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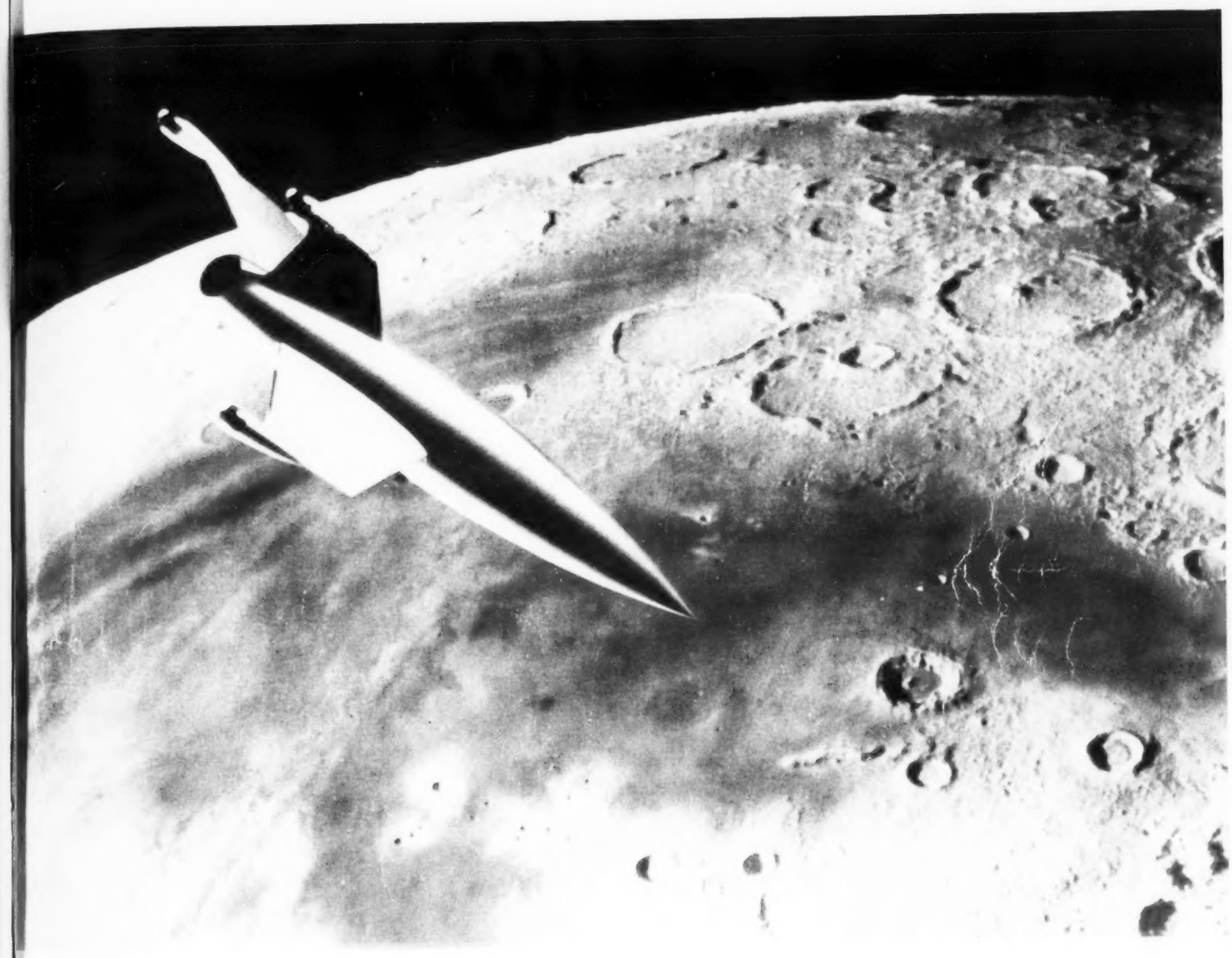

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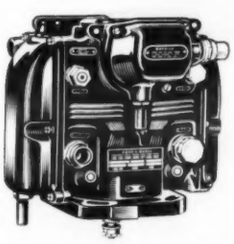

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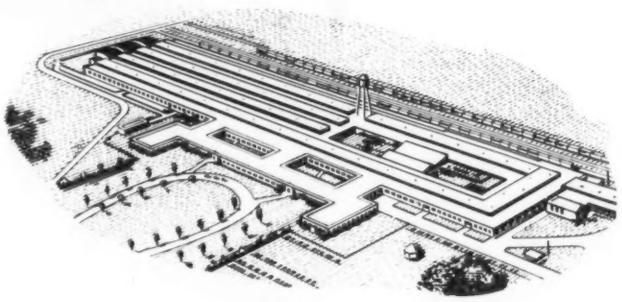

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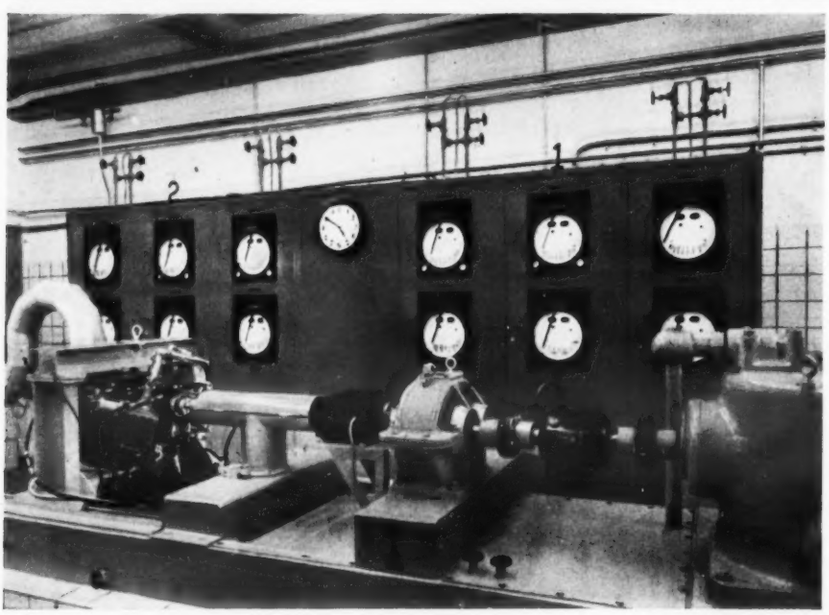

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The Age of Rocket Power

Readers of this month's issue will find pictures of the moon, of artificial satellites orbiting around our planet, of spaceships and interplanetary voyagers. Those who have time to spare may derive some enjoyment from the illustrated story of the first trip to the moon. Some may recall their youthful enthusiasm for Jules Verne.

We know perfectly well, of course, that some of our readers might think that a wave of *lunacy* has wafted through our editorial staff. Well, we assure them that we still have our feet firmly on the ground...

Meanwhile, it did seriously occur to us that the first experiments carried out by the Chinese thousands of years ago, or the partial incendiary destruction of Copenhagen by British rockets in 1807, not to speak of the ill-conceived attempt in 1944 to regain by rocket power a lost supremacy in the air, do give one food for thought.

Also, if we are to be accused of over-enthusiasm for such matters, then some of the highest placed men in Washington's Pentagon would likewise be candidates for earnest psychiatric treatment. We trust that none of our readers has forgotten that, not so very long ago, an American Secretary of Defense admitted freely that the US Military Establishment was concerned with research for placing artificial satellites around the Earth. Nor do we suppose that anybody considers the Peenemünde experiments, the current test firings in the Californian Mojave Desert, in the Pacific, in Australia and numerous areas of the Soviet Union, as mere games conceived by puerile minds.

Rockets are now part of the standard inventory of every military power. Rocket motors have proved their ability to propel aeroplanes. They are the object of continued research as aggressive weapons. Attempts to establish mail lines by rocket have been going on for several decades. It is more or less possible to determine where rocket development began. Where it will end... belongs in the realm of fantasy.

It strikes us as being of secondary importance as to whether rocket propulsion will remain confined to chemical propellants—as most experts firmly believe to-day—or whether nuclear energy will find new application in this field. Ask the man-in-the-street what he thinks of rockets and he will no doubt answer that he considers them to be secret, deadly weapons. But if you contact one of the relatively small circle of scientists now established in all countries, you will be told that the rocket is to-morrow's medium of transport, which will one day enable us to set up connections with our neighbouring planets... The vehicle of a coming interplanetary generation.

Just reflect a while ! Had a serious scientist risked predicting, thirty or forty years ago, that 1950 would see transport aircraft carrying forty or more passengers regularly in about twelve hours across the Atlantic, or had an engineer foreseen merely that supersonic flight might be accomplished by 1950, then people would have ridiculed them. There is no doubt that most people to-day regard with similar misgivings the few pioneers who now dream or speak of interplanetary travel.

We do not wish to suggest that interplanetary travel will come about in the immediate future. Still less do we maintain that even the approximate foundations are yet established for such undertakings. Our opinion is only that interplanetary travel is one of man's dreams which will one day be realized. When ?... Well, even we might live to see the day when people chide us for our present cautious opinions.

To confine oneself always to finished constructions, to speak of aircraft only as commercial commodities when they are already perfected, is tantamount to overlooking the possibilities of to-morrow. But the true journalist must not only report ; he must also incite interest. For this reason we are devoting the first section of this issue to a description, not without fantasy, of something in store for our next generation : Interplanetary Travel.

The East and the West Present Arms

In the meantime, those readers who find that our own planet causes enough worry will also find something worth reading.

Last September at Farnborough, the Society of British Aircraft Constructors staged its usual annual exhibition and display. Our engineers, although they saw no revolutionary new designs returned very favourably impressed. As regards the quantity production of the British aircraft industry, present-day political conditions make it difficult to make anything beyond a very approximate guess. But there was no doubt about the high quality of Britain's modern turbine aircraft. It was a presentation of arms in the West, which may have caused many a fighter pilot's heart to beat faster...

Meanwhile, it so happened that, at roughly the same time, an envoy from the Kremlin chose to call on us with a few photos and more than usual information about the Soviet Air Force. The interest of our engineers was strongly aroused for this glimpse behind the Iron Curtain was decidedly informative. We saw that the Russians had picked up numerous ideas from former German as well as modern British and American designs and developed them. We saw clearly that the Soviet Air Force is now equipped with the most up-to-date of fighters and bombers, fitted with high-power turbine engines. It could be concluded that Russian manufacture is not merely confined to high quality, but also that major quantity production is well under way. A presentation of arms in the East, too !

EEH.

The Shape of Ships to Come

BY WILLY LEY, JACKSON HEIGHTS, NEW YORK

Willy Ley, since 1935 active as a rocket expert in the U.S.A., is the author of numerous books on rocket technique and interplanetary travel: Rockets *(New York, 1944)*, Rockets and Space Travel, *New York, 1947)*, Vorstoss ins Weltall *(Wien, 1949)*, The Conquest of Space *(New York, 1950)*.

When, just before the turn of the century, the inventor *Hermann Ganswindt* advanced the first seriously meant, if quite crude, space travel plans (on the basis of a ship propelled by explosion "pills"), he ran into a solid wall of general disbelief. Only a single critic even felt it worth his while to reply. He was *Román Baron von Gostkowski,* professor at the Technical High School of Lemberg. Writing in the Viennese periodical *Die Zeit,* he told his readers, and Ganswindt, that a ship propelled by dynamite or similar explosives could at best reach the limits of the atmosphere which he assumed at 360 kilometers. That was in 1900 and although professor von Gostkowski simplified his methods of calculation too much for accurate results he was, inessense, correct under the assumptions made.

About a quarter of a century later, in 1925, it had been shown mathematically by *Robert H. Goddard* and *Hermann Oberth* that, with the aid of the step principle, a rocket should not only be able to penetrate to the limits of the atmosphere, but that it could also reach the moon. The discussion had come to the point of accepting the general theory but of doubting whether engineers could build what theory demanded.

Now, again a quarter of a century later, a two-step rocket, consisting of a V2 and a WAC-Corporal, has actually reached the limits of the atmosphere and unless all the rumors are wrong, official studies on a satellite rocket are progressing. It will probably take much less than another quarter of a century to accomplish both, the unmanned rocket to the moon and a satellite rocket revolving around our own planet. But in all probability much more will be done between now and 1975.

Until a few years ago it was still possible to reason as follows : of course there is no doubt that rocket theory as developed by Oberth is mathematically correct. There also is little reason to doubt that the engineering problems are in themselves soluble. But with chemical fuels only the realization of space travel was a project of such magnitude that it could be doubted for reasons apart from mathematics, engineering and technology. With chemical fuels only the unmanned rocket to the moon—the Moon Messenger as I call it to distinguish it clearly from a manned spaceship—could certainly be realized. A manned trip around the moon, without landing there, seemed a faint possibility. Of course it also appeared possible to put a large rocket in an orbit around earth and once that was accomplished the rest would be rather easy, for a rocket taking off from the station would have a velocity relative to earth of the order of 4.65 miles per second (7.5 km/sec) before it used up a single kilogram of its own fuel. That was *Guido von Pirquet's* "cosmonautical paradoxon" which stated that the first step would be harder than any other afterwards. But one could doubt—mostly for financial reasons—that this very long first step would be taken.

But now we know how to extract energy from some heavy atoms. So far, according to released information, we can do mainly two things : either make this energy appear in the form of an explosion, or else heat water with it. Neither is suitable for rocket propulsion but hopes that a suitable method can be found are now justified. One may imagine, for example, that the fuel of an atomic-powered spaceship consists of a watery solution of a uranium salt where most of the uranium atoms are of the fissionable U-235 variety which are made to split when they enter the rocket motor. Or one may hope for a method of expelling an inert reaction mass, plain water or possibly mercury, without expelling the fissionable matter along with it. In such a manner the ideal combination of factors may be established : very high exhaust velocity, high density in the tank and low molecular weight of the exhaust. At any event a ship with a mass-ratio of 3.5 : 1 which can take off from the ground, go to the moon, land there and return to earth for an airplane type landing was just a dream ten years ago. By now this dream has advanced to the status of a justified hope.

"Moon messengers" within this decade ? Even to-day it is possible to accelerate the crewless end-stage (uppermost component) of a very large multi-stage liquid-fuel rocket to the necessary velocity of liberation of at least 7 miles per second, so that with the aid of lunar gravitation it finally can fall to the moon's surface (maximum travel duration : four days).

While one still has to be somewhat vague about the propulsion mechanism one can be fairly definite about most other things. In external shape such a ship, no matter what its overall size, will resemble the V2 rocket or rather the Peenemünde type A-9 with short wings. The problem here is to create a wing type which during the vertical take-off of such a ship acts merely as a stabilizing fin but which will function as an airplane wing when the ship, empty and therefore light, returns from space. The ideal would be a retractable wing but this presents so many design problems, all unsolved, that one may forget about it for the present. Besides there exists a rather simple way of making the wings non-functioning during the early part of the ascent where they might be most disturbing. They can simply be hidden in the take-off booster.

The ship will probably have a take-off booster just because it is atomic powered. Atomic energy inevitably carries with it the problem of radio activity. Protecting the pilot and passengers from the radiations emanating from their own propulsion machinery is not too awkward. The internal arrangement of a spaceship should not be confused with the arrangement of an ocean going vessel ; it is the arrangement which would prevail in a tall and narrow tower. Therefore all the shielding necessary would be a "floor" or bulkhead at one point and this shield will, obviously, be the lighter the narrower the ship. The atomic powered ship, far from being squat, will be longer, or rather taller, and more slender in proportion than the big rockets of today. But one has to anticipate that the exhaust blast might be radio active too. For a first test one could simply pick a remote area and leave it to the Ecuadorian police to keep people away from the contaminated spot afterwards. But as soon as one has more than one departure a month there has to be a permanent spaceport and that must not be radioactively contaminated. Therefore the ship would be carried for a mile or two by means of a booster with chemical fuels.

There will be another place for a small chemical fuel rocket motor in such a ship. After the period of initial acceleration of a few minutes is over and the ship is in "free flight"

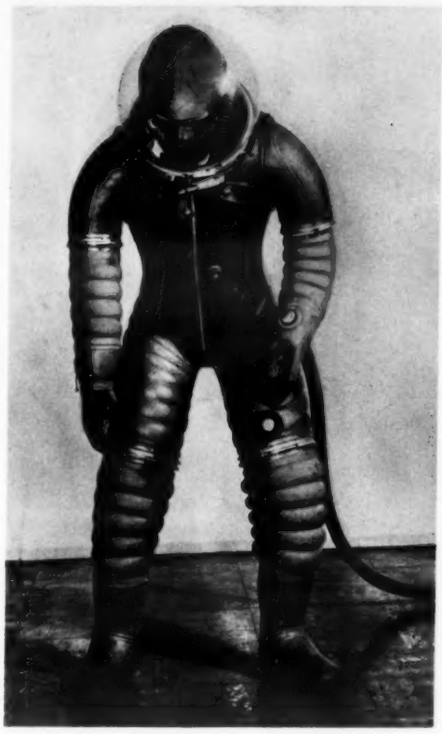
the effects of gravity will be absent, except for the very slight effects of the heaviest parts of the ship herself. When the time for additional firing either for orbit correction or for landing has come nothing might happen. Because the distribution of the liquid reaction mass in the tanks (and also of the liquid fuels in a large liquid fuel rocket) is very much up to blind chance. There is absolutely no guarantee that the liquid, once the tank is more than half empty, will be where the standpipes can get it. One would, therefore, need a small rocket motor, capable of delivering a thrust of some 200 kilograms for two or three seconds to cause the liquids in the main tanks to settle where they belong. Such a small motor could either operate on compressed *gaseous* oxygen and compressed methane or it could simply be a cordite rocket. It is the equivalent of the starter on an airplane engine, but the starter is needed only in space, not for take-off.

Since the entrance would be located above the shielding bulkhead a structure for entering and also for servicing would be needed of which the Gantry Crane on the White Sands Proving Ground is the prototype. At White Sands, where one has to climb steel ladders to get up, everybody feels a bit like a fireman when something has to be adjusted in the instrument head of a V2. Of course elevators would be provided for the still taller spaceships and since the servicing structure is apt to weigh more than the ship the White Sands procedure will probably be reversed. At White Sands the rocket remains in place while the crane moves away. For bigger structures it would be more practical to place the ship on a movable firing table.

It cannot be too strongly emphasized that the normal attitude of a spaceship is vertical, whether standing freely on the ground, taking off or landing. On our moon, for example, since it is airless, the only way in which the velocity of the ship, imparted by the moon's gravitational attraction, can be reduced to zero is by landing tail first, with the motor working. There will probably be shock-absorbing "outriggers" of some kind to take care of minor unevennesses of the surface. Not only that it could hardly be done any other way, this method of landing tail first has the additional advantage that the ship is at once and automatically in take-off position after landing. The only exception to this rule of vertical position is the return landing on earth with empty tanks where the ship lands as a high speed glider ; at first probably on water. But even then the ship is apt to float in a vertical position after it has come to rest.

Astronomers and also meteorologists have often stressed the fact that our atmosphere is a protective blanket. It absorbs most of the ultraviolet radiation from the atomic furnace which we call our sun. It swallows the cosmic rays. It burns up virtually all meteoric matter except the very large ones. Because the protecting qualities of our atmosphere have been stressed in such a manner there are now very many people who expect that several awful fates will befall anything that sticks its nose out of the blanket.

As regards the ultraviolet radiation from the sun we already have some experience. Naturally the ultraviolet could operate only through windows, not through the metal of the ship's wall. And here the sequence of development has been this : ordinary glass absorbs ultraviolet and since the small quantities of it which we experience here on the ground are beneficial, it was greeted with much joy when types of glass and of transparent plastics were developed which did not hinder the passage of ultraviolet. But when these types were used in high-altitude aircraft it quickly developed that they permitted the ultraviolet to pass too well for comfort. For this reason there are now types of shatterproof glass sandwiches and also of transparent plastics which keep the ultraviolet out, more so even than the cheap window glass which was blamed for doing just that. Ultraviolet proof spaceship windows, therefore, are no problem. Of course the windows, in turn, should be protected by sliding metal shutters during take-off.



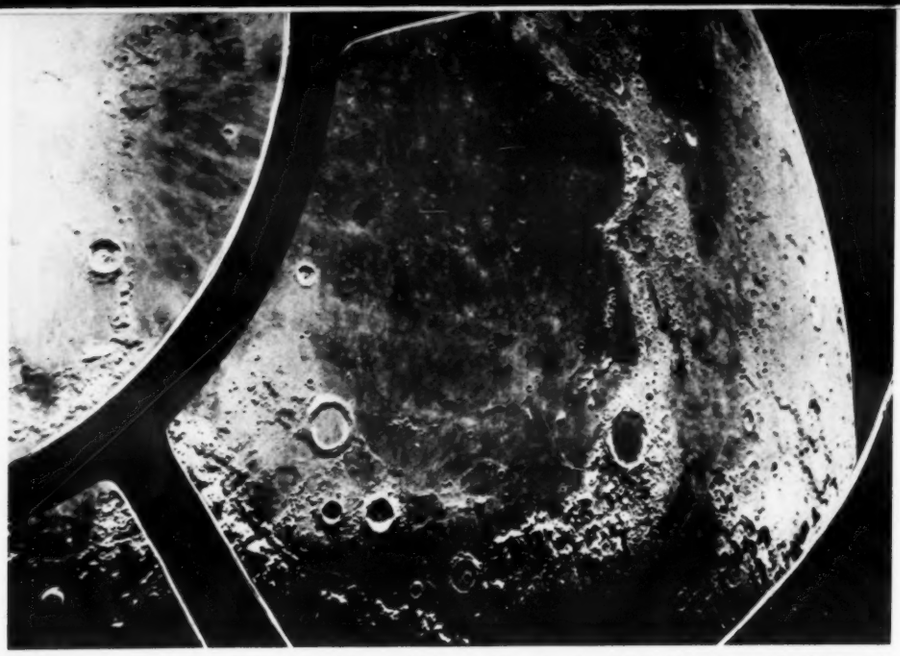
In the case of manned research and exploration ascents to a relatively small altitude, the crew could be protected from the danger of sudden cabin pressure reduction (caisson disease) by pressurization equipment such as that now used for high-altitude flight. On the moon, which has no atmosphere, pressure suits would be indispensable outside the space ship.

As regards the problem of cosmic radiation experimentation especially with Aerobee rockets has already provided an answer. It was found that there is a "cosmic ray ceiling," a height of maximum intensity, some thirty miles above the surface. But even there the amount of radiation is below that which is considered "safe" in atomic energy laboratories. Above this "ceiling" the radiation density decreases quite fast to reach a very low value higher up. Of course at an altitude of say 100 miles the bulk of the earth still shields the instruments against roughly half of the total radiation. For a position far from the earth, say half way to the moon, the figure for 100 miles altitude would have to be doubled. But even if it were quadrupled it would still be far below the "safe" limit of atomic laboratories.

The problem of meteorites is somewhat different. It is impossible to draw conclusions from estimates which say that the earth is struck hourly by one or two million meteorites of all sizes, even aside from the fact that the estimate is not too certain itself. Obviously there is an enormous difference between a solid ball like the earth, 7900 miles in diameter with a strong gravitational field, and a spaceship, some 200 feet tall and 20 feet in diameter with no gravitational field to speak of. Furthermore meteorites, like fish, come in all sizes and the big ones are rare. The vast majority will have a mass below one gram. What complicates judgment still more is the problem of their velocity. It is easy to calculate that a ship, en route to or from the moon and piloted by a man with bad luck may be struck by a meteorite with a relative velocity of three miles per second. What nobody knows is what will happen when a meteorite strikes a metal plate with such a velocity. One is apt to think of ballistics and to conclude that the penetrating power should be some function of the velocity. But even in ballistics this holds true only within limits, a much faster bullet may not have the penetrating power which would follow from its velocity because it deforms itself on impact. And in the case of meteorites we don't deal with bullets but with bodies of approximately spherical shape and with an average density of only 3.4. (The much rarer iron-nickel meteorites, of course, have a density near 7.8.) In short, nobody can tell for certain just what their penetrating power might be.

The next question concerns the number of meteorites that might be encountered. This has been investigated mathematically by G. Grimminger of the Rand Corporation in Santa Monica. One of the tables drawn up by Grimminger deals with the probable number of hours of waiting time between hits if a spaceship is in the general vicinity of the orbit of earth. For meteorites of a diameter of 13 millimeters the table gives the figure of 5.36 times 10^9 hours. For meteorites of a diameter of 5 millimeters the figure reads 2.09 times 10^8 hours, for meteorites of a diameter of 1.1 millimeters it is still 2.04 times 10^6 hours. For microscopic meteorites of a diameter of 1/100th of one millimeter the probable time interval between hits is slightly over two hours.

The danger that a spaceship will encounter a large meteorite which would penetrate a solid hull like a machine gun bullet is obviously negligible. It is equally obvious that a spaceship will have to sustain a number of hits of microscopic meteorites on every trip. For this reason *Prof. Fred L. Whipple* has suggested a special precaution which he called a "meteor bumper." It consists of a sheet of metal one millimeter in thickness mounted at a distance of say 25 millimeters outside the ship's hull. This outer sheet would absorb all the impacts of bodies which could be seen only with the aid of a low power microscope. Those that would penetrate through the "bumper" would have their velocity reduced very considerably



1975 ? On the way to the moon in an atomic-powered space ship. An extremely inviting crater and *maria* terrain (or rather lunain), probably formed by the impact of large meteorites, is seen to be coming into view. Large mountain ranges, probably surpassing even the Himalayas, are also to be found on the moon.

so that it is not likely that they could penetrate the hull proper.

It will probably not be necessary to encase all of the ship with such a bumper. The principle is that of having two layers of sheet metal at an interval and for much of the engine compartment etc. this will be the case. For these sections the hull of the ship will be the "bumper" and the structural casings of the components the "skin." The bumper will be essentially a feature of the sections accessible to crew and passengers. The reason why these sections have to be especially guarded against meteoritic puncture is, of course, that the air would escape. Here quite a number of additional precautions are possible. For experimental trips which are just supposed to go a few thousand kilometers into space and then to return, possibly after circling the earth once or twice, the simplest thing would be to have the crew wear spacesuits from take-off to landing. Since such "test flights" would be of a duration which can be expressed in hours one can expect the crew to put up with the inconvenience of wearing a spacesuit continuously for their own safety.

For a lunar voyage, which would take anywhere from 30 to 100 hours, depending on the velocity attained, the steady wearing of a spacesuit would constitute a considerable hardship. One of the precautions taken would be to surround the wall of the cabin with a layer of sponge rubber of the type holding separate air bubbles. If the hull and the rubber is punctured the area around the puncture would tend to expand and to seal the leak. The seal might not be perfect but it would delay the escape of air. And in order to avoid the possibility that the crew may be stricken with a sudden attack of "diver's disease" or "bends" the atmosphere inside the cabin would differ from the open atmosphere at sea level. The cause of the "bends" is that the inert nitrogen of the atmosphere goes into solution in the bloodstream. When the external pressure is suddenly reduced some of the nitrogen leaves the solution and appears in the form of bubbles in the blood vessel. One cannot change this characteristic of nitrogen, but one can substitute a different sort of inert gas in the spaceship's atmosphere. Exhaustive tests made in the United States with diving equipment have shown that helium is nearly perfect for this purpose. Helium does dissolve in the bloodstream too, but to a much lesser extent. Hence bubble formation on sudden decompression is almost negligible. As for the people involved : they can't tell the difference whether they are breathing a nitrogen-oxygen atmosphere or a helium-oxygen atmosphere.

Up to this point it was possible to give a general description of what a future atomic-powered spaceship would be like : long and slender in shape, with wings for return landing, internal arrangement of space following the pattern of a narrow tower, windows of ultra-violet proof glass protected by sliding metal shutters while moving through the atmosphere, meteor bumper for especially vulnerable sections and a different type of atmosphere inside the cabin. But for some of the other foreseeable features there will be differences, partly according to the purpose of the ship, partly according to destination. The latter does not refer so much to the conditions at destination, but to the duration of the voyage.

The length of time required for a trip to our nearer neighbors in space, Venus inside our orbit, Mars outside our orbit and the moon next door in our own orbit naturally depends on a large number of different factors. It is not a problem like navigating a plane from Ireland to Newfoundland. It is a navigational problem which would have come up if the various floating islands of classical mythology had (A) actually existed and had (B) carried on commerce with one another.

The duration of a trip to Mars or Venus would first depend on the relative positions of the moment which implies greatly varying distances. Secondly it depends, naturally, on the assumptions made for velocity, fuel capacity and so on. For these reasons only one set of figures is at all useful for a preliminary survey, those which, so-to-speak, show the worst that can happen. The worst possible conditions are, obviously, the minimum of expendable energy at which the trip can still be made at all and, simultaneously, the greatest distance that is astronomically possible. These figures were provided for the first time by the late *Dr. Walter Hohmann* over twenty years ago and read : 146 days for the one-way trip to Venus ; 258 days for the one-way trip to Mars.

In the case of the moon the variation in distance c. 1 almost be neglected because the limits are within ± 6 per cent of the average center distance of 384,000 kilometers (239,000 miles). With minimum energy expenditure a moon trip will take four days, the variations caused by distance count in hours only. Obviously a ship which is to be in space for just four days will be different in some features from one which may have to be in space for eight and a half months. But since the velocity changes involved, which is the same as expenditure of reaction mass, for the three destinations just mentioned vary by comparatively small factors the differences in design apply more to the features for passenger comfort than to the propulsion mechanism. In fact one may say, with some simplification, that an atomic-powered ship which can easily make the roundtrip to and from the moon could also make the trip to Venus and Mars. provided only that more reaction mass for the return can be taken on after those planets have been reached.

One of the major differences between a ship assigned to the lunar run and one with Venus or Mars as destination would be the instrumentation. During a lunar run the pilot would be interested in only two factors, the distance of the ship at a given instant from the goal and the velocity of the ship at the same instant. This could be done by measuring the apparent diameter of the moon at suitable intervals by means of a telescope and then checking the apparent diameter against the actual distance in tables prepared for that purpose. In reality this astronomical method will be reserved for apprentice pilot training and when the radar set is undergoing repair. Normally the radar set will provide the same information more accurately, much faster and with less trouble. It is true that direction of sighting (visually or radar) and direction of motion do not coincide precisely so that corrections will have to be applied, but the closer the ship approaches the moon the closer the coincidence between line of sight and line of motion.

Position finding during a trip to Venus or Mars is something which is slightly more complicated, requiring equipment that may not even be carried on a moon trip. When going

from one planet to another the ship too travels in a planetary orbit which, like the planetary orbits, is elliptical with the sun in one focal point. The difference is that the eccentricity of the ship's orbit is higher than that of the orbits of the major planets. Because the ship is moving in such an orbit, the astrogator has to find his position with respect to the sun rather than with respect to either home planet or goal. The latter comes afterwards. To establish his position the astrogator first has to find the star Regulus which is conspicuous, easily identifiable and happens to be situated very nearly in the plane of the ecliptic, and at a very great (almost infinite) distance. Knowing that the astronomical longitude of Regulus is 150° and measuring the angle of sun-ship-Regulus the astrogator can establish the astronomical longitude of his ship. The next job is to take a sight on a conveniently located planet, not necessarily the target planet. He then has a triangle formed by sun, ship and the planet used. Of that triangle he knows the length of one side (sun to planet, from the handbook for that date) and also the position (longitude) of that side. Since he already knows his position relative to the sun and Regulus, the remaining work is not even trigonometry anymore but merely a question of consulting the right table. Once the ship is reasonably close to the target planet, Regulus is no longer needed and radar can take over instead.

The second major difference between a ship on the lunar run and one bound for a neighboring planet would be the method of handling supplies for the crew, which includes a breathable atmosphere. For a moon trip this is a minor problem. Food and drink will be what is customary, the helium of the atmosphere is inert, it is just a question of replacing oxygen and removing carbon dioxide. For a moon trip one would just carry the necessary oxygen along, naturally in liquid form because the heavy steel cylinders required for compressed gas would be a waste of carrying capacity. But it might be equally wasteful to carry chemicals for the removal of carbon dioxide. Many years ago Professor Oberth suggested circulating part of the cabin's atmosphere at intervals into a long pipe outside the ship and in the ship's shadow. It would then radiate its heat away and moisture and carbon dioxide would freeze out of the air while the oxygen, the nitrogen and especially the helium remain gaseous for a long time. This principle might easily be expanded into an automatic apparatus but one which would be used for the lunar run only.

On a voyage the duration of which has to be measured in months neither the moisture in the cabin's atmosphere nor the carbon dioxide should be wasted by letting it escape into space. One also does not dump scrap metal into the ocean. To condense the moisture of the atmosphere, produced by skin evaporation and exhaled breath is a simple technological problem and after it has been distilled over and flavored it can be used again. As regards the carbon dioxide a machine is fairly helpless. The answer here is another living thing: plants. Plants will take the carbon dioxide and convert it into their own substance and edible starch, releasing oxygen in the process. Nor are the quantities excessive: a leaf surface of one square meter will provide enough oxygen for one man doing sedentary work. It seems that certain fast growing fresh water weeds provide the largest amount of oxygen and the process can be speeded up by some tricks of illumination, one of which is a short three or four hour "day" followed by a "night" of equal length.

Naturally the oxygen-producing plants and the oxygen-consuming crew do not need to occupy the same room, especially since this method would be used only on fairly large ships. This principle will probably be referred to as that of a "balanced aquarium" and that term would be correct in the sense that people *think* that an aquarium operates that way. We now know that it doesn't, enough oxygen goes into solution in an aquarium even if not a single plant is present. What the plants in an aquarium are for is to remove the carbon dioxide; that they produce oxygen too in the natural course of events is obvious, but not required. But a spaceship cabin would actually be the closed system which an aquarium is supposed to be.

To go into medical problems would require a separate article, but it can be stated that no single bodily function is known which depends on gravity. Some, like swallowing, are aided by gravity but do not depend on it as is already shown by the fact that one can swallow against gravity. On any trip into space, gravity seems to be absent as soon as the rocket motors have ceased working. This means that gravity seems to be absent most of the time, for on a 97 hour moontrip the rocket motors would work for a total of about ten minutes. 97 hours are not enough to let the muscles deteriorate for lack of strenuous activity. This would be different for the weeks or months required to reach another planet. Some exercising machinery, depending on springs, not on weights, would obviously have to be part of the standard equipment. And exercise hours would be part of the regular routine. They might help to do a little against the one factor which really looks bad. That is not a physical factor but a psychological one. Whether you call it, according to your upbringing, boredom, *ennui* or *Langeweile*, it is the thing against which space travellers have to guard more carefully than against anything else.

For the foreseeable future only three goals seem attainable. Mars with its thin air, less than that over the peak of Mount Everest, its reddish deserts and its patches of vegetation which we are now sure exist. Venus, the surface of which is a complete mystery to us because it is always hidden under white clouds. And Eros, the little planetoid which crosses the orbit of Mars and therefore comes closer to earth on occasion than the red planet. Because it offers no appreciable surface gravity which would make great demands on reaction mass for take-off, Eros might be the first goal of a longer-range interplanetary expedition.

The moon, of course, will be first. And if things progress on the accelerated curve which has held true for the last 25 years somebody may get there in 1975.

1980 ? A lunar base with bunker living quarters and wireless station has been erected, an atom rocket arrives from and takes off for the earth every week. Here it is being prepared for take-off on the return journey by men in pressure suits. The scene is illuminated by reflected light from the home planet; the more remote mountain ranges are lighted by the rising sun. (From "The Conquest of Space," illustrated by Chesley Bonestell, text by Willy Ley, published by Viking Press.)

Earth Satellite Vehicles

BY R. ENGEL, BRUNOY, FRANCE *

Ever since that laconic statement in the Forrestal Report of December, 1948, on the "Earth Satellite Vehicle Programme of the USA," in which the late American Defense Secretary *J. W. Forrestal* revealed that the creation of space bases and their equipment had been allocated to the Committee on Guided Missiles, intense discussion concerning interplanetary travel and space stations has been going on.

Meanwhile, the general public remains comparatively ignorant with regard to the basic questions involved. Nor is this to be wondered at, inasmuch as rocket technique and research have until now been the exclusive field of a restricted number of specialists. New developments are placed under stringent secrecy measures by all participating States, with the stereotyped explanation of "Military Security." Beyond all question, this state of affairs is a hindrance to normal progress, since objective and unprejudiced criteria of judgment are withheld from the public. As a consequence, interplanetary travel has become as much the object of the most severe scepticism as it is of the most uncritical enthusiasm.

At any rate, the arguments concerning the possibility of establishing an extra-terrestrial station necessitate a priori a very sober approach to the question. Admittedly it would be interesting—but relatively useless—to outline plans for the interior installation, the sleeping and working quarters of such a space station, or to compose fantastic reports as to the uses to which artificial terrestrial satellites might be put. This can be left to the writers of pseudo-scientific fiction.—More than 200 futuristic technical thrillers on the theme of interplanetary travel demonstrate sufficiently that the topic has met with avid interest amongst the technically uninformed. Of considerably greater and more immediate importance is clarification of the physical and technical conditions, as well as the estimation of the costs involved in the construction of such an extra-terrestrial base.

CRITERIA FOR THE CHOICE OF A TRAJECTORY

For the sake of simplicity it is assumed in the following considerations that the station describes a circular orbit about the earth. This does not necessarily have to be the case ; elliptical orbits are also possible. As regards circular trajectories and their altitude above the surface of the earth, the purpose of the station is naturally the decisive factor.

Here it can be presumed with immediate certainty that the first interplanetary station will serve exclusively research purposes. Our knowledge with regard to conditions in the highest layers of the earth's atmosphere (beyond 300 km) is so scant and the physical and physiological problems involved in the final conquest of this domain are so manifold, that even after the first station becomes practically operative, considerable time will elapse before the newly acquired information can be exploited. On the other hand, if the first station is to be a pure research base, the altitudes available are already subject to *limitation :*

The orbit of such a station must lie beyond the actual atmospheric envelope of the earth, i.e. at an altitude of over 500 km. At the same time, its distance from the earth must not be too great as otherwise the transportation of supplies would be too costly and investigation of the high-altitude atmospheric layers (200-400 km) from the base impossible. Furthermore, the conditions of stability and disruption of the trajectory have to be ascertained, the predetermination of which our general geo-physical knowledge does not as yet permit to a sufficient degree. For this purpose, it is especially necessary in the case of the first station to be able to take continuous measurements from the earth, the more so because the station will initially be too small to provide an accurate basis for measurements. Rapid and simple observation of small deviations is possible, however, only when the orbit is so chosen that the station appears at regular intervals at the same point above the earth surface relative to the observation center.

This latter condition applies to "*oblique*" *orbits* (i.e. those which form an angle with the plane of the earth's equator) only if the station's time of rotation about the earth amounts to a fraction of the earth's own period of rotation about its axis (86,400 stellar seconds). But even with *equatorial orbits* (in the plane of the earth's equator), observation is considerably simplified if a whole number of rotations takes place daily. Without wishing to enter into a discussion of astronautical methods of calculation at this point [1], it may be stated that in the case of fifteen daily rotations (in oblique orbit) an altitude of 557 km can be calculated and the orbital velocity amounts to 7,582 meters per second. When there is a daily trajectory of 12 rotations, however, the altitude amounts to 1,669 km and the orbital velocity to 7,039 meters per second.

An easterly direction of rotation (i.e. the direction of the earth's rotation) will, of course, be chosen for the satellite vehicle, inasmuch as any body rising from the earth's surface gains the additional velocity of its terrestrial take-off point in the case of "eastern flight," which otherwise (i.e. in the case of "western flight") it would have to overcome.

A further question is that of the portions of the earth's surface to be observed from the planetary station. To gain an idea of this, it may be mentioned that with an orbital inclination of 30°, 70 % to 90 % of the earth's surface is visible, whilst with a 60° inclination 99 % of the entire surface of the earth lies open to observation. This state of affairs is probably of considerable significance for every "non-civil" operation of the space station.

For the final choice of a trajectory, light and heat conditions are also important. During every rotation the station traverses the earth's shadow for a short period of time. Hence, the "day and night" distribution is of primary consideration for work in the station. This distribution should be so constituted that the base lies within the light zone to the greatest possible extent. The determining factor for this is the position of the orbital plane relative to the solar-terrestrial eclipse.

Finally, there is the question of cosmic radiation, which constitutes not only an object of research but chiefly a very serious danger to the presumable crew of the space station. Our present-day knowledge—despite all efforts at ionospheric research—is unfortunately not sufficient to enable us to make a definite statement. In this respect, we shall have to wait for the data obtained by the high-altitude research rockets now in construction and on trial in the USA. In this connection, it is possible that similar though nevertheless better instrumental combinations, such as that of an A4 and "Wac Corporal" tried out in February, 1949, are already capable of attaining the lower limits of the altitude range which will be assigned to space stations.

Inasmuch as the present outline is concerned only with the orders of magnitude of all the significant factors, an orbital inclination with an average value of 45° is assumed ; correspondingly, the declination relative to the solar-terrestrial eclipse amounts to 68°. In order to make clear the effect of altitude, it is sufficient to compare directly both orbits, namely of 557 km (orbit I) and of 1,669 km (orbit II) altitude. Our first illustration shows both orbits as seen from the northern pole of the trajectory, i.e. approximately from the direction of the star "Beta-Aurigae." The direction of rotation of the station and the axial direction of the earth's rotation are indicated by arrows. Of even greater clarity for purposes of judgment is the orbital picture projected onto the earth's surface, i.e. the connecting line of all points of the earth's surface over which the station is in zenith at specific times.

The duration of sojourn within the earth's shadow, of importance for the working conditions on the space station, amounts on the annual average to 24 minutes per rotation (= 25 %) for orbit I, and to 17.8 minutes (= 15 %) for orbit II. It is not possible to enter into greater detail here concerning the undoubtedly interesting problem of temperature control. It may merely be pointed out that the sun irradiates the station at a rate of 19 kcal/m² (medium solar constant) per minute. Thermodynamic calculation shows that it is therefore possible to obtain quite satisfactory room temperatures on the station.

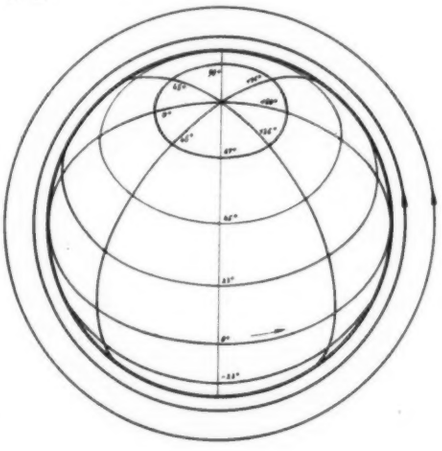
EXTRA-TERRESTRIAL BASE AND GROUND ORGANISATION

Before "establishing" the first extra-terrestrial station, a number of crewless rockets will undoubtedly first be sent up and experimental flights will have to be made likewise with crew-carrying types. These experimental projectiles—just as subsequently the base station itself—will circle about the earth freely, though they cannot be looked upon as extra-terrestrial bases as such. Purely technical considerations show that the dispatch of a crewless satellite is in no way essentially simpler than the construction and ascent of a manned station. For this purpose, a number of radio-technical innovations will be necessary, inasmuch as hitherto conventional high-frequency communication technique breaks down owing to the effects of ionospheric radiation.

A functionally practical station designed for a crew will in its final constructional stage have to comprise the following divisions : 10 cabins, 6 laboratories, 1 tool shop, 1 power station. How these divisions are to be distributed cannot be gone into here. It is possible, as a primary gross estimate, to state—inasmuch as aluminium alloys are presumed to be the constructional material—that they will have an overall weight of approximately 180 tonnes. As to equipment (installation, instrumentation, machinery, etc.), a total of about 330 tonnes will be necessary. Thus, the total weight stipulates a transport output for 510 tonnes.

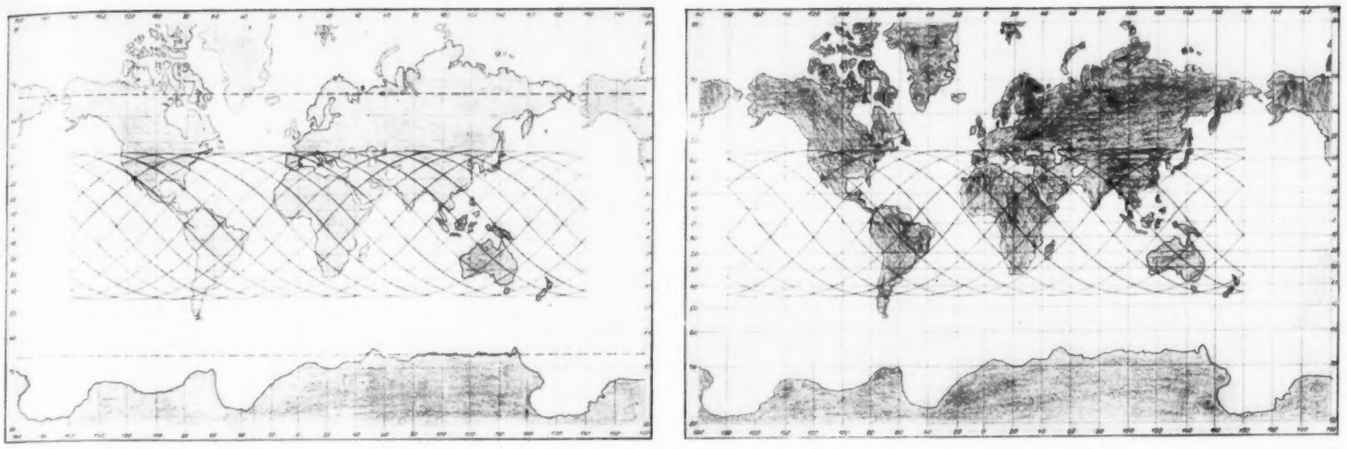
If a transport performance of two tonnes is assumed for each feeder rocket, of which approximately 0.3 tonnes can be subtracted as consumable material for an average crew of 20, then 300 supply rockets would be necessary. Since the transported construction material has to be concurrently utilized by the crew of the station, a rocket will be sent off on the average only every 3 days to the station, i.e. about 125 rockets annually. Of these, approximately every fifth will be a return vehicle, so that only 100 transport rockets as such will remain per year. In such a case, construction time would amount to approximately three years, and construction costs to about 500 million dollars. The greater part of this material will have to be transported gradually by feeder rockets of a uniform type, in the current supply traffic to the upper orbit.

Scale representation of orbit I (at 557 km altitude) and orbit II (at 1669 km altitude) at an orbital inclination of 45°.



[1] Cf. Dr. E. Sänger "The Laws of Motion in Space Travel," INTERAVIA, Review of World Aviation, No. 7, July 1949, p. 416-418.

* The following article is an excerpt from a survey by R. Engel, U. T. Bodewald and K. Hanisch entitled "The space station—a project for the future ?" which appeared at the ONERA in Paris.



Projection of orbit I (left) and orbit II (right) onto the world map in Mercator's projection: Each orbit traverses the equator only $2n-2$ time in the course of a day, since the earth rotates at the same time once in the same direction. Consequently the intersection of the orbit with the equator undergoes a $360/n$ towards the west per revolution. The area of visibility is limited to a noteworthy extent only in the case of orbit I and indicated by means of broken lines.

For the continuous operation of such a station, a comprehensive *ground organisation* is needed. This can be subdivided, according to its tasks, into a supply station, a communications station, and a measurement and observation station. In the case of the first, we would be dealing practically with a "take-off base," from which the rockets necessary for the continual supply of the satellite with constructional materials, food, etc., would depart.

The *communications stations* are responsible for the maintenance of uninterrupted wireless communication with the satellite, which is possible only so long as the corresponding ground base lies within the momentary optical field of vision of the satellite. Thus, for orbit I, a total of at least 27 communications stations is necessary, distributed on latitudes 34° north, 0° and 34° south at intervals of 40° longitude. In the case of orbit II and under most favourable conditions, 12 communications stations on latitudes 27.5° north and 27.5° south, with a longitudinal interval of 60°, would suffice.

The *measurement and observation stations* have the task of exercising a regular check on the period of rotation of the satellite, *e.g.* with a sextant. Inasmuch as this type of check calls for extreme precision, land stations will have to be chosen. Otherwise, no further restrictive conditions apply to the choice of these observation stations except that they must lie within the total zone of visibility.

FEEDER AND RETURN ROCKETS

The question as to what types of special apparatus will serve to constitute the nucleus of the space station cannot be entered into here. On the other hand, it is of considerable interest to determine the appearance and nature of the *feeder rockets* responsible for the continuous supply of the station in building or already installed. For this purpose, an investigation of the optimum trajectory of ascent necessary to attain the orbital velocity at the desired altitude (synergy trajectory)[2] is of the utmost interest. The following phases can be distinguished:

A) The trajectory of ascent which leads away from the layer of atmosphere (resistance) at moderate acceleration and in a perfectly or almost perfectly perpendicular direction. The trajectory traversed under power is followed by a more or less long motorless vertical ascent.

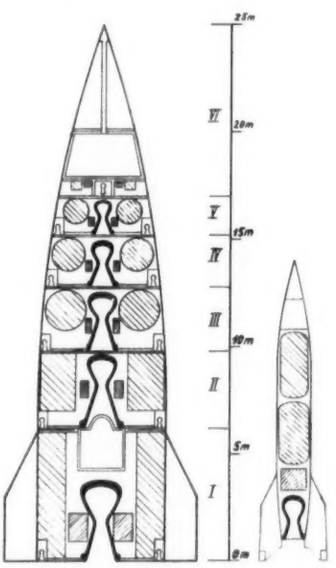
B) The trajectory of directional change which converts the hitherto vertical path—in point of fact a path already considerably oblique as a result of the earth's rotation—further into an almost horizontal direction, either by gravity or by utilizing the rocket's thrust.

C) The trajectory of acceleration, over which chiefly speed is to be attained without any considerable gain in altitude, so long as is necessary to reach the orbital velocity requisite to this altitude (here designated as "lower orbital velocity").

D) The period of waiting spent in free gravitation without power at the previously mentioned altitude. This time interval serves for the control and eventual correction of the trajectory, with particular regard to the angle of phase relative to the station which the ascending rocket is approaching on the lower orbit as a result of its shorter period of rotation.

E) The transitory impulse necessary to accelerate the rocket from its lower orbital velocity to the speed corresponding to the perigee of the bridging ellipse (i.e. the ellipse whose lowest point is situated on the lower orbit and whose peak—apogee—is situated on the final, "upper," orbit of the station).

Schematic drawing of a six-stage supply rocket for the space station in comparison with the single-stage V2. The initial stage provided with four stabilizer fins contains (above the propulsion unit) a pressurized cabin with an observation canopy for the "landing pilot." Whilst the first five stages are each equipped, apart from the main propulsion unit, with four control jets for directional changes and the correction of disturbances, the terminal stage has a manipulable and finely regulable jet both for propulsion and steering. The pressurized cabin of the terminal stage transports two pilots and all measuring and control instruments. Above it is located the cargo hold for the supply of the satellite base.



F) The upward sweep by virtue of which the rocket ascends to the upper orbit without further power as a result of the additional velocity gained from the transitional impulse (bridging ellipse). Here, the rocket circles about the earth for a half rotation and its sole function under way is to regulate its velocity so that it will arrive at the proper orbital altitude and in the required direction.

G) The peak impulse which accelerates the rocket from its speed at the peak of the bridging ellipse (remaining after the upward sweep) to the "upper orbital velocity" (i.e. that of the satellite), in order to avoid falling back to the lower orbit. We cannot enter here into detail concerning the question of the "docking procedure" terminating the ascent at the station.

For a transport capacity of about 2 tonnes at an orbital altitude of 557 km (orbit I), it will be necessary to choose, with today's fuels and jet exhaust, speeds of 2,180 meters p. sec. (in the atmosphere) and of 2,900 meters p. sec. (outside the atmosphere), a *six-stage rocket with a take-off weight of 220 tonnes*. With an orbit at the altitude of 1,669 km (orbit II), the take-off weight would amount to as much as 300 tonnes. From this it may be seen how important is the choice, from the very beginning, of orbits not too remote from the earth. Calculation and constructive checking indicate (for orbit I) the following take-off weights and *Brennschluss* (cut-off) speeds:

Stage VI	5,000 kg	7,582 meters/sec.	(temporarily
Stage V	10,800 kg	7,815 meters/sec.	7978 m/sec.)
Stage IV	23,320 kg	5,880 »	
Stage III	50,400 kg	3,985 »	
Stage II	110,500 kg	2,130 »	
Stage I	220,000 kg	820 »[3]	

The initial stage (I) is to operate in vertical climb only and separate after power cut-off (*Brennschluss*) in order to land at a not too remote distance after controlled descent. The stages II-V function in such a way that when the fuel consumption of stage V is completed the lower orbital velocity (in a horizontal direction) at an altitude of 100 km is *almost* attained.

The velocity, however, should be somewhat smaller than the corresponding orbital speed so that the exhausted stage V now jettisoned will not ensatellite but will again reach the earth. Provision can be made for its decomposition into smaller parts in order to reduce the dangers particularly inherent in this stage by the dispersion of its presumed landing point.

It is assumed that in each stage thrust remains constant throughout. The advantages of constant acceleration can be reserved for later "passenger vehicles." Here it suffices to remain below the limit of six G. Stage II has to operate at a lesser acceleration since it will be responsible chiefly for the change of direction. Up to and including stage V, the trajectories

[2] According to *Oberth*, the whole complex of questions necessary for the determination of the most favourable ascent procedure is to be designated as "a problem of synergy." In a somewhat more extended sense of the phrase, these ascent trajectories are consequently designated as "synergy trajectories." They are determined according to the method of the calculus of variations.

[3] After complete fuel combustion and jettisoning of the initial stage at about 12.7 km altitude (after 35 seconds), the remaining aggregate continues during 48 seconds in free ascent to an altitude of 37.2 km, whereby its velocity is reduced to 345 meters/sec. It is only then that stage II is fired.

MAN-BUILT SATELLITES

Scientists are not yet in agreement as to the form and size of their projected Earth Satellite Stations. However, there is one point on which they all agree; namely, that the state of weightlessness aboard an artificial satellite—due to the equilibrium between terrestrial gravitation and centrifugal force—must finally have adverse physiological effects on the crew. For this reason it is thought to have the greater part of the station—at least the recreation rooms, and perhaps also the study quarters—rotate about its own axis. A British proposal (by R. A. Smith) foresees a roundabout arrangement, with eight living rooms located at the extreme periphery, a central power station (with control devices, climatization equipment, etc.) and work quarters situated halfway along the radius. The project illustrated here, which, designed by Erich Menzel, is taken from a film entitled "Rockets in Interplanetary Space," due to be issued shortly by the "Institut für wissenschaftliche Filme" in Erlangen, Germany, provides for crew quarters in a rotating "pear." The mirrors connected by cables with the station are for illuminating certain areas of the Earth. Professor Oberth suggests using parabolic mirrors to collect heat energy, and finally electrical energy from the sun's rays, in which case they should be coupled rigidly with the station. *Ed.*

of ascent for both terminal altitudes (557 km and 1669 km) do not have to differ; it is only with stage VI (whose propulsion plant is no longer jettisoned) that different trajectories are taken to attain the terminal altitude.

In the adjoining illustration the initial portion of the trajectory of ascent as seen from the orbital pole of the space station is presented. At the points 1-6, the stages I-VI begin to operate. Stage I terminates at about 13 km altitude; the stages II-V are jettisoned at the points 3-6. The flight trajectories of the empty stages are indicated by broken lines. It is the absolute trajectory which is indicated, so that the apparently vertical ascent and descent of stage I is seen as curvilinear. After point 6 (jettisoning of stage V at 7815 meters/sec.), stage VI has initially to accelerate up to the lower orbital velocity (7845 meters/sec.); then follow the period of waiting, the transitional impulse (up to 7978 meters/sec. for orbit I), the upward sweep over the bridging ellipse and the peak impulse (from 7452 up to 7582 meters/sec. for orbit I) as well as the final docking. The overall duration of ascent amounts to about 60 minutes.

For all practical purposes, the initial stage, whose weight amounts to about half of the overall weight of the entire aggregate, should be salvageable for further operation. Even though the cross-section loading of the empty rocket will amount to only about 500 kg per square meter—this characteristic can be reduced to about 350-400 kg/square meter by extending the braking vanes which are designed to hold back stage I after complete fuel combustion—the terminal fall velocity will nevertheless be in the range of about 100 meters/sec. and hence must be compensated by opposing thrust. For this reason, the initial stage will have to have a reserve fuel for descent. In addition, it will be necessary to have a "landing pilot" carried with the initial stage, who will then bring it back safely to earth.

Stages II-V are crewless. Their flight ranges in the trajectory plane will terminally be shortened by air resistance; the point of landing will be determined by the earth's rotation during the period between take-off and touch-down. For instance, if the take-off base is situated in the center of Australia (at 22 ½° South and 135° West), that is to say in the region which is already projected for experimental long-range rocket trials, stage II would still touch down in the northern territories, stage III on the Cape York peninsula, stage IV in the Coral Sea and stage V in the Atlantic.

Understandably enough, the question of return to earth also arises. The pilots arriving with the supply rockets must, of course, be able to depart again from the space station. These *return flight problems* are, it is true, somewhat more involved, but nevertheless equally solvable. Presumably, developments will lead to the construction of special "return rockets" to be interpolated between the supply rockets. Such return rockets would then transport their payload during ascent in the form of a highspeed aircraft specially developed for return to the earth (which during climb, owing to its bulk, would be partially dismantled and in this form brought to the space station and assembled there only).

The return flight can be thought of approximately as follows: By means of a weak impulse, the return aircraft initially separates from the station until the necessary distance for security is attained. Thereupon, its speed is reduced to the value of the peak velocity of the bridging ellipse by means of a stronger impulse (approximately 300 meters/sec.). By this means, the return aircraft succeeds in attaining a "lower orbit," after a half-rotation of the earth in the direction of movement of the station. The altitude of this lower orbit is so chosen that a certain braking effect results from the air resistance of the thin high-altitude atmosphere. The altitude loss connected inevitably with this effect allows the return aircraft to approach the earth nearer and nearer throughout a closely-pitched spiral trajectory.

To what extent this trajectory of descent becomes a "cycloidal" glide with slowly decreasing amplitude, as a result of the lift forces acting on the supporting wing and the aerodynamic "supporting" fuselage surfaces which become effective with increasing air resistance, depends on the choice of the return aircraft's dimensions and the selection of the trajectory of descent. Thanks to thorough investigations by Dr. Eugen Sänger, this question is already susceptible of calculable solution [4], so that, together with the present available experimental data concerning supersonic flight, a technical solution of the problem of return is possible. Hence, after the return aircraft has sufficiently reduced its speed and flight altitude during repeated rotation about the earth, it can glide down to a supply station or other airport. It goes without saying that a sufficient amount of fuel must be available on board in order to undertake the necessary trajectory corrections and to permit landing itself.

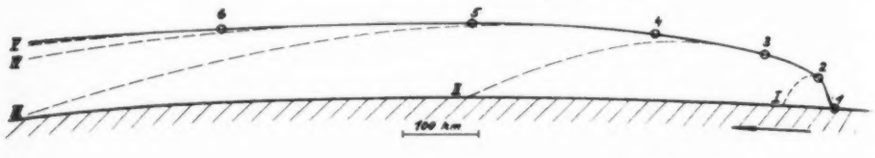
*

It is perfectly possible that other reasons may prove of decisive importance in the choice of an orbit for the space station, or that other ascent procedures might be preferred in order to reach this orbit. In all probability, the supply rocket will in its final form take on a quite different appearance to that outlined here. The order of magnitude of the figures previously cited, however, will not be changed to any essential extent by such alternative possibilities. With this data, expenditure estimates can be made which show that the construction of such extra-terrestrial bases is feasible not only in the technical but also in the financial sense. Hence, in conclusion it may be said that the construction of an interplanetary station is by no means a task for the remote future, but can be begun in the immediate present.

*

Lateral projection of the optimum trajectory of ascent of a feeder rocket:

1. Take-off of the initial stage (I).
2. Firing of stage II (stage I has already been separated).
3. Jettison of stage II; firing of stage III.
4. Jettison of stage III; firing of stage IV.
5. Jettison of stage IV; firing of stage V.
6. Jettison of stage V; stage VI accelerates for the lower orbit.



[4] Cf. Dr. E. Sänger "The Prospects of Jet Reaction Flight" in INTERAVIA, Review of World Aviation, No. 11, November, 1948, p. 621.

This Moon Madness

BY SCHOLER BANGS, LOS ANGELES

Einstein, I think, might be somewhat bewildered by the telling.

Six-feet-tall men shrinking to under five feet.

Voices booming through space where there is no air, and echoing back.

Infinity that you can reach out and touch, and has the feel of black velvet.

Strong men spending two long days walking a distance of ten feet, one hundred thousand miles outward bound from Earth.

A sight-seeing stroll completely around the fifteen-mile rim of a crater on the Moon—three minutes, walking slowly.

Relativity gone completely mad, irrational!

But when you've had a good dinner, and settled down with the memory of the smile of the attractive red-head who sold you your admission ticket; and the screen suddenly is suffused with brilliant make-believe, everything suddenly clicks back into place.

Time, space, and the affairs of the four adventurers hurtling moonward, and back again, all become logical and leave one quite ready to live with them man's first flight to the Moon—in Technicolor.

In fact, you find yourself wondering, with the audible audience about you:

"I wonder... it seems so reasonable... it could be that way... well, couldn't it?"

Which, of course, is exactly what Hollywood hopes you will wonder as you come away from seeing "DESTINATION MOON."

At one time the producers had hoped that it would be a smash attraction as America's *first* interplanetary travel thriller; the first space travel melodrama since Germany's offering at the time Oberth and the others were fooling around with nasty little experimental rockets which made the life of a rocket scientist interesting and a poor insurance risk.

The advertising was ready, and publicity was beginning to flow, when there was dirty work at the crossroads of Hollywood and Vine.

Another studio tossed together a fantasy in ten days of frantic camera shooting, titled it "ROCKETSHIP XM" and hurried before the eyes of movie fans with ads explaining that "XM" stood for "EXPEDITION MOON."

Filmdom's top gossip columnists momentarily were frozen in their tracks, eyebrows and envenomed pens poised, awaiting the resounding slap and... at dawn; ten paces!

All that came of it, though, was the deletion of "EXPEDITION MOON" from the "ROCKETSHIP XM" advertising.

It still didn't help matters much.

Producers of "DESTINATION MOON" no longer could hope to beat the drums of publicity with first showing of a space travel picture.

All they had left was an excellent movie which at the moment is brightening the eyes and bank accounts of theater owners who had trembled at the prospect of another space ship story in a matter of weeks after they had shown "XM."

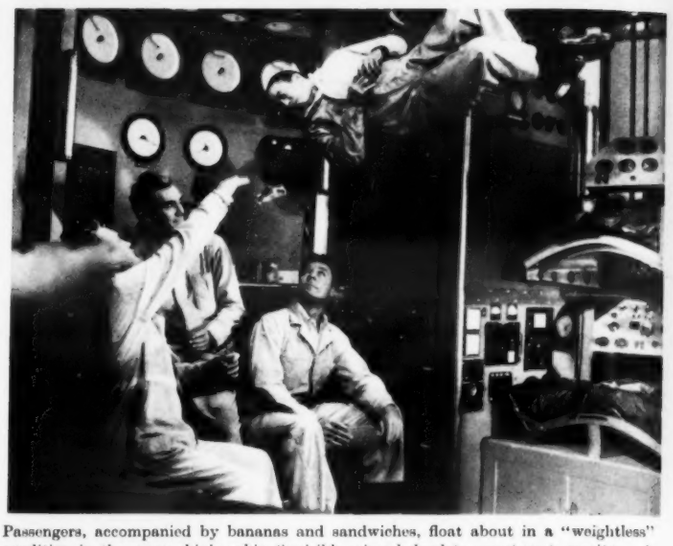
An excellent movie despite the fact that it violates the tradition of Hollywood.

It is probably the most sexless movie ever filmed.

For one briefly lingering moment a woman is in the picture, the wife of Dr. Cargraves saying farewell as he is about to board the towering space rocket poised on the Mojave Desert. She is there for a moment, then gone. And it is quite all right as far as the audience is concerned.

All set for the ride to the moon, this 150-ft. colossus of sheer, shiny steel is standing on a... dining-room table.

Invisible wires fastened by strips of adhesive paper make the intrepid astronauts pucker their faces as though under the influence of an acceleration of several 'G'.



Passengers, accompanied by bananas and sandwiches, float about in a "weightless" condition in the space-ship's cabin (invisible wires helped to counteract gravity . . .).

How George Pal, the producer, ever sold his financial backers on putting even the scant $1,200,000 which "DESTINATION" is supposed to have cost into a movie sans sex remains one of the lighter mysteries of Hollywood.

Maybe he told them with a self-answering question :

"Where are you going to put women in a space ship which can only carry four, and they have to be men ?"

And :

"Besides, we're going to have problems enough."

Problems ?

They were all over the place when I visited the set just as they were settling down to the really serious shooting of the action midway between Earth and Moon a gargantuan, barnlike building, the biggest sound stage on the lot.

Already a precious, costly day had gone by trying to get three of the spacesuit-clad stars to float "weightless" in the neutral gravity of outer space, out of an open hatch in the side of a silvery section of rocket hull lying securely timbered in position on the floor.

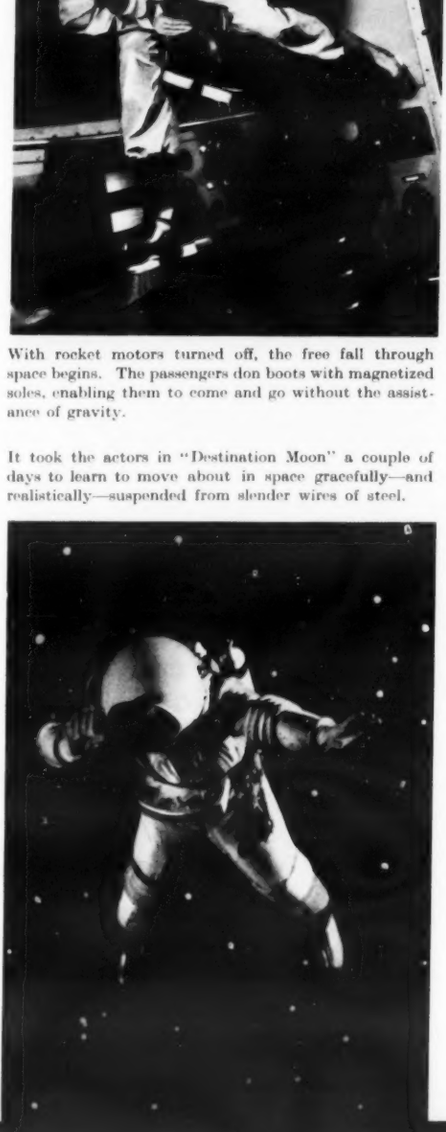
Time after time crews of husky prop hands just out of camera range at either end of the hull had grabbed ropes and run at the cry of "Camera ! Action !". And time after time the red, blue and green-suited figures in the fishbowl helmets had popped into view dangling and swaying at the ends of piano wires attached to body harness concealed within the suits.

They were to attempt repair of a collapsable radio antenna mast which had frozen in outer space.

"Two days, and they can't even walk ten feet !"

With rocket motors turned off, the free fall through space begins. The passengers don boots with magnetized soles, enabling them to come and go without the assistance of gravity.

It took the actors in "Destination Moon" a couple of days to learn to move about in space gracefully—and realistically—suspended from slender wires of steel.



There was anguish in the voice of the assistant director as he said it.

My good friend Bob Heinlein, sitting in a director's chair with a blanket about his shoulders ; nursing a miserable cold and surrounded by a forest of spotlights, ladders, electricians, publicity men and third assistant cameramen gave a hollow laugh, half cough.

It was to be our first meeting, and maybe our last, but film lot tradition holds that the most casual contact be one of "God, its good to see you after all these years old pal, old pal, old pal !"

Ben Babb, the publicity and advertising master mind of "DESTINATION" had suggested it, and pointed him out :

"I want you to meet Robert A. Heinlein, the famous space travel novelist who wrote the original script for 'DESTINATION MOON.' Just watch out for his cold. Its a dilly."

As the colored figures again popped out of the rocket hull with jack-in-the-box awkwardness Heinlein chuckled again.

"Its marvelous ! I'm supposed to be the expert on these sequences, on what happens in outer space. And so. I just sit here, nursing a cold."

I had thought that his job had been completed with the writing of this. I had in my hand a "final revised script."

With an air of resignation he said that the script wasn't his story.

"About all that is left in there of my original writing is a few pages of technical notes in the script appendix. . . sort of a guide for accuracy in some of the shots. In fact, I'm guessing that great big chunks of the 'final revised script' will be missing when you finally see the picture on the screen."

A dramatic incident in the film : during a tour of inspection around the space ship's hull, the magnetized boots of one of the explorers lose contact with the ship, leaving him faced with the prospect of remaining forever a "celestial body" lost among the stars.

Propelled by the jet reaction from oxygen bottle, another astronaut comes to his rescue (rescuer and rescued were both suspended from steel wires, about a foot from the floor of the studio. A safety net was used in certain takes . . . just in case the "weightless" actors might still have a few pounds too many left in them !)

Mr. Heinlein, author, apparently had "discovered" Hollywood !

Apparently the timing between rope pullers and actors piano-wired for space flotation had been coordinated.

"Qui-et ! This'll be a take."

The outer doors of the stage swung closed. All was in darkness except for yellow puddles of light dimly illuminating, for safety, the cable-strewn floor about the camera stands.

"All right, lets have the stars !"

The seemingly limitless void of black velvet curtains draped from ceiling to floor in a vast semi-circle beyond the rocket hull instantly blazed with a thousand little lights, rendered as coldly blue as distant stars by filter coverings.

"Lights !"

From high in the rafters batteries of carefully angled spotlights "hit" the space ship hull with dazzling impact.

"Its a take ! Roll 'em !"

Swiftly, smoothly, one behind the other, as easily as if they'd been doing it all their lives, the helmeted figures of the space explorers came floating up out of the open hatch. Their colored garb glowed with glittering brilliance under the hot lights, and they briefly stood poised in realistic "space" against the background of countless stars before they turned and walked side by side slowly around the far side of the curving hull and were lost to view.

The cameras were not running on sound track at the time, so the squeak of pulleys and straining of ropes as they were lowered to maintain their "upright" position walking around the hull didn't matter. And the camera didn't "see" far enough around the hull to catch them concluding their "walk" lying with simple dignity, still half-supported by their wires, in a safety net just off the floor.

"Cut it !"

The spotlights faded to angry dull-red eyes above. The stars suddenly vanished. The seemingly aimless throng of production workers began milling about again. Pal, the producer, a small man with eager, quizzical eyes, turned his head upward. High above, on the camera platform, the cameraman smiled and nodded : "It looked pretty good from where I sit."

Doors opened. California sunlight flooded in. And the man with the garden spray watering pump slung over his shoulder resumed his spraying of the splintery wooden floor as if he really hoped that roses suddenly would appear and burst into bloom.

Actually, he was wetting down the "stardust" of this spot one moment in Hollywood and the next 100,000 miles away.

"All this walking around," explained a cameraman, "raises particular hell with trying to shoot space that is supposed to be filled with nothing at all except stars and the space ship. That's why we keep wetting down the floor. When the spots are turned on even a little dust floating in the air is likely to show up on the film as a light, shifting fog. We

Having landed safely in the crater Harpalus, the explorers rig up a Schmidt telescope. Above, at left : the Earth.

just hope, after we've made a take, that the rushes will show that we've missed it. Angling the spots just so, helps some, just as the cut-and-try angling of the spot beams helps us to fade out the piano wires."

The actors again were on the top of the hull, waiting for the next scene while workmen with long poles ran sponges soaked with lampblack up and down their supporting wires to kill the light reflection on the silvery strands.

Behind us, cradled in massive gimbal rings which allowed it to be rotated in two directions at once before the baleful eye of the camera, the instrument-cluttered "cabin" of the space rocket was being readied for a retake of a sequence which had been rejected when the daily rushes had been shown.

Rotated to horizontal position or upside down as the rocketship crew walked with magnet-soled boots it gave to the camera, also rotated on its side and upside down, the perfect illusion of the crewmen walking easily up the cabin walls and across the ceiling of the tiny room.

Near by, in another sound stage building, the "Moon" was being readied for shooting of the sequences in which the spacemen land perilously on the crack-scarred plain within the crater Harpalus, the dun-colored rim rocks of the "vast" crater blending into the Lunar landscape stretching beyond as far as the eye could see.

"Its about fifteen miles around the rim as you'll see it in the finished picture. Care to walk around it ?" Babb asked.

The space and surface distance that was breathtaking as we had stood in the entrance door dwindled suddenly to disappointing reality as we walked around the huge circular "table" supporting the crater's surface, following a narrow corrider on the far side of which a giant, ceiling-high landscape mural encircled the set ; a laboriously executed painting laid out by the noted "planet" artist Chesley Bonestell.

As the true size of the "Moon" set came into focus Babb sensed my question.

"I know. What will we do in this small space to make the actors appear relatively small as they move out of the close-up shots and start walking away across the surface of the crater ?

"Its quite simple. We'll shrink them until they fit into little, tiny space suits !

"But really, what we'll do is this. After the close-ups we'll do a switch between shots, using professional midgets in small suits, and planting a nine-foot model of the rocketship over there on that level spot so that with the midgets fairly sizeable in the foreground it will appear that they are 'exploring' the landscape a mile or more distant from the rocketship."

All very reasonable as he outlined it. Yet, standing there with the cruelly harsh landscape stretching out around and above us, beyond the crater, it was fantastically eerie. To think that we had encircled the crater in not more than three minutes, strolling slowly ; to hear our voices leap back at us from across what must be assumed to be an airless land.

I should have liked to have been present when Dr. Fritz Zwicky, the noted astronomer and astrophysicist was a visitor on the Moon set.

Babb, gag-minded, thought what a wonderful stunt it would be for Dr. Zwicky to have ill-concealed on the papers on his desk a photograph of himself standing in Crater Harpalus, with Earth glowing brilliantly above the distant peaks in the background. What he had in mind was strictly from Hollywood.

Or was it Moon madness ?

"Can you imagine the effect when, some day, a Top Brass General from the Pentagon drops into his office to ask the Doctor what he thinks are the chances of achieving outer space flight... and then, out of the corner of his eye, he sees that picture on the desk !

"Dr. Zwicky would only have to ask, in reply, one little question : 'Are you sure, General, that it has not already been done ?'

"The General wouldn't dare ask questions about anything so top secret that he hadn't heard of it. Boy ! What a flail that would stir up when he got back to Washington !"

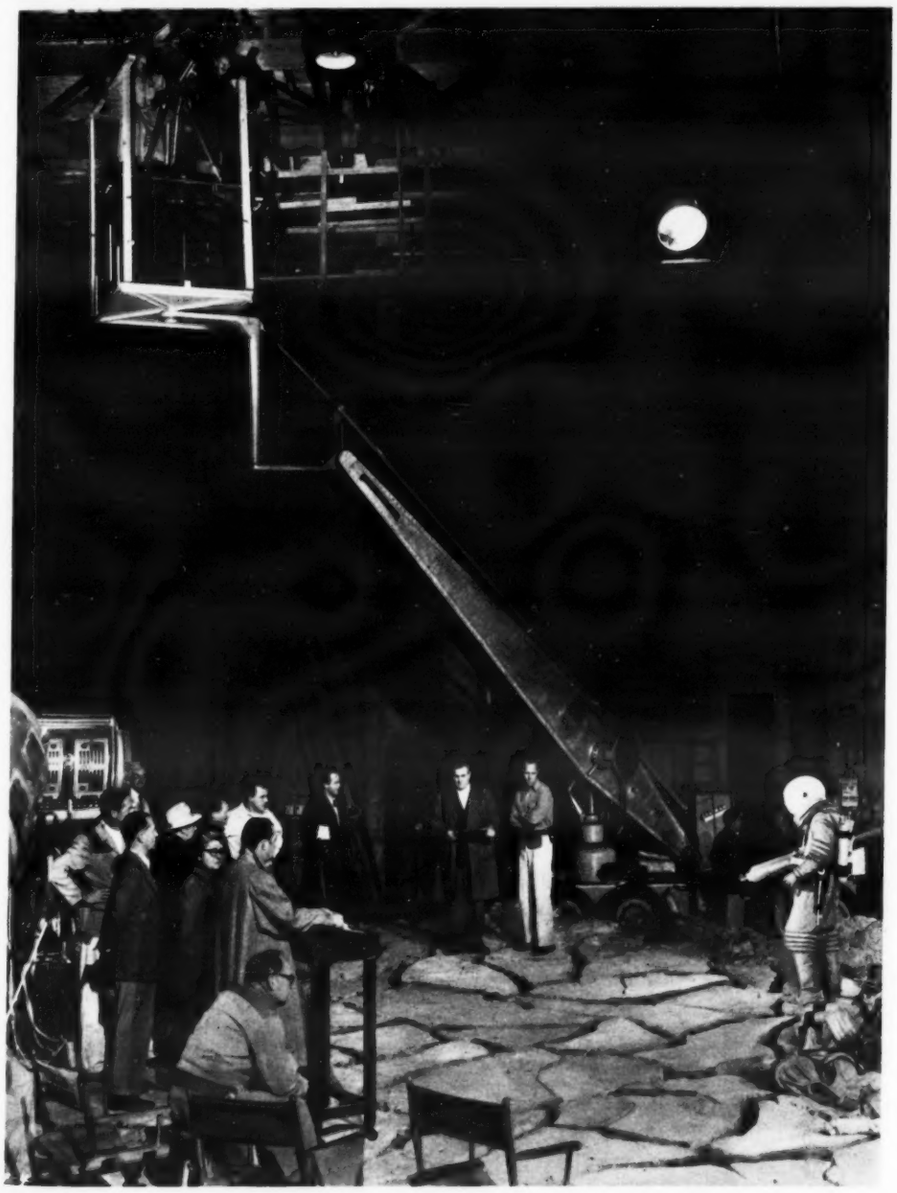
The Moon set does things like that to you.

Out in the sunshine, walking back across

Midget actors had to be used in this scene to make the proportions "ring true." The "distant" space-ship is just nine feet high.

Back to their normal size again, the lunar explorers choose the equipment that they will jettison to lighten their space-ship for its journey earthwards.

Shooting in progress on one of the "Moon" scenes.



the lot, Babb figured that maybe it might not be such a good idea after all.

All about us lay the litter of the massive props, the huge tail fin section of the rocket-ship, the big cranes and camera booms, all used in capturing the excitement-packed story of man's first landing on the Moon.

Yet the props and gear for some of the biggest, in size, scenes in the entire picture could be rested on the space of your office desk.

For example, the night takeoff scene on the desert where the rocketship rests poised for the blast-off of its nuclear reactor motor. Cars, dwarfed beneath the 150 ft. high monster, swerve about the slender steel framework of the gantry supporting the elevators in which the crewmen ride up to the space ship's flight deck near the nose. As the warning siren wails the automobiles dash away to safety, and slowly the gantry frame moves away from the ship.

The entire sequence actually is a "process" shot made in a laboratory with a rocketship model standing only three feet high and surrounded by a toy gantry which required three weeks to build.

The takeoff sequence, inside the cabin, was made in the gimbal-supported structure on the sound stage, and with tiny wires running to adhesive to pull the faces of the actors into agonized disfiguration as they are crushed down into their takeoff couches by the force of a 6-g. acceleration. Once the "speed of escape" is reached, and the rocket blast is shut off, faces are eased from the pulling tension, and the crew can enjoy the televised picture of the receding Earth.

A "process" shot, though, and one which puts one on seat's edge, is the "televised" shot from the space ship toward the Moon's surface as the rocket drops tail first upon its blast column and narrowly misses a jagged Moon peak on the way down to a rough landing.

It is "good theater" from start to finish—a finish which leaves the space conquerors safely off the Moon's surface and en route home.

You are forced to assume that all will end well on the Earth below, or above if your mind still is with the heroes in their cramped cabin.

It avoids the problem of distracting you by having women, wholly foreign to the plot, appear suddenly on the scene with floral wreaths, tears, kisses and the like.

It lets you stay with your dream as the screen goes blank and a post-title suddenly appears in giant lettering :

"THIS IS THE END...

"OF THE BEGINNING !"

Astronautics Enthusiasts

BY ALEXANDRE ANANOFF, PARIS

PRESIDENT OF THE FIRST INTERNATIONAL ASTRONAUTICAL CONGRESS

Striving to attain the same sublime ideal, men throughout the most diverse countries of the world have placed their knowledge, means and time at the service of the cause of astronautics.

It is their story that we now propose to relate. The reader will find here names and dates, but, in perusing this article, he will scarcely be aware of the sacrifice, the fight at all moments that only sincere faith could sustain against ignorance and scepticism.

RUSSIA

In 1896, Constantine Edvardovitch Ziolkovsky, intrigued by the semi-scientific considerations outlined in the "New Principles of Interplanetary Navigation" by A. P. Feodoroff, enthusiastically devotes his time to a study of the daring perspectives to be discovered there. In 1903, the fruits of his research are synthesized in a simple schematic description of a cosmic rocket. Basically simple, it is true, but how prophetic...

His investigations, the study on "Sideration," published in 1910 by Dr. Jakov I. Perelman, the articles by the engineer M. A. Zander appearing in 1911, all foreshadow the foundation in 1924 of a *Commission for Interplanetary Communication* at the Academy of the Red Fleet in Moscow by Professor W. P. Vetchinkin, to whom we also owe a number of mathematical memoirs on interastral navigation. In the course of the same year, the first review on reaction, entitled *Raketa,* was to have appeared, but the project was not realized.

In 1928, the *Sekzia isledovania problem mejplanetnih soobchteni* (Section for the Study of Problems relative to Interplanetary Navigation) is founded at the Institute for Bridges and Highways in Leningrad. The first international astronautical exhibition, organised by Professor Feodoroff, is held in the same year.

In November, 1929, Dr. Jakov I. Perelman and Professor Nikolai Alekseievitch Rynin establish in Leningrad and Moscow the *Groupa Izoutechinia Reaktivnovo Drijenia* (Group for the Study of Propulsion by Reaction), commonly called *Mosgrid* and *Lengrid.*

These movements remained in close contact with K. E. Ziolkovsky who, at the age of 72 years, continued from his place of retirement in Kaluga to give generous advice to all those manifesting enthusiasm for astronautical science [1].

Up to 1935, various movements of greater or lesser importance are initiated and later go into oblivion ; in 1936, a number of sections are formed in Moscow and Leningrad under the auspices of official government bodies.

The most important is the *Reaktivnoia Sekzia* (Section for Reaction) of the *Stratospheric Committee of the Union Ossoviahim USSR,* who periodically publish the *Reaktivnoie Drijenie.*

GERMANY

It is indisputably to the remarkable work of Professor Hermann Oberth, « *Die Rakete zu den Planetenräumen* » (The Rocket to Interplanetary Spaces), 1934, that we owe the foundation in June, 1927, by Engineer Johannes Winkler of the *Verein für Raumschiffahrt* (Association for Interplanetary Navigation), and the monthly publication throughout three years of the review « *Die Rakete* » (The Rocket). In 1930, the Society was transferred to Berlin. Its Committee was composed of H. Oberth, Hoefft, Valier, Hohmann ; within the first few years more than 500 members were recruited [2].

During the next ten years there are practically no active societies, the efforts of the engineers being directed towards practical projects and the Government of the Third Reich having forbidden all propaganda dealing with rockets.

On June 18, 1937, Hans K. Kaiser founds, first in Breslau and later in Berlin, the *Gesellschaft für Weltraumforschung* (Society for Interplanetary Research) and is highly active up to the war. For purposes of propaganda, the Society distributed a leaflet inserted in all numbers of the "*Astronomische Rundschau*" (Astronomical Review) and from January, 1939, it published its own bulletin, "Weltraum" (Cosmos).

After the war, in 1946, administrative difficulties putting a brake on all initiative, the principal collaborators of former times decided to establish local societies in Western Germany, in order later to reconstitute the organization of 1937. In 1947, Dr. W. Goethe founds the *Südwestdeutsche Gesellschaft für Weltraumforschung* (South West German Society for Interplanetary Research), authorized by the US Military Government on February 5, 1948, in Frankfort. Its program deals exclusively with the study of theoretical problems.

In the same year, in Hamburg, Hans K. Kaiser founds the *Nordwestdeutsche Gesellschaft für Weltraumforschung* (North West German Society for Interplanetary Research), officially authorized by the British in 1950. Vice-President is H. J. Rückert, formerly an engineer at Peenemünde-West, and Director of the Scientific Committee is Gerhard E. Janzon, a former associate of Professor Oberth. The Society edits its own periodical. In 1948, at the instigation of H. Gartmann and H. H. Kölle, an *Arbeitsgemeinschaft für Weltraumfahrt* (Study Group for Interplanetary Navigation) is formed at the Stuttgart Observatory ; about 40 students of the Polytechnikum constitute the active nucleus of the Society. In June, the movement assumes the name of *Gesellschaft für Weltraumforschung e.V.* (Society for Interplanetary Research) and publishes the journal "*Weltraumfahrt*" (Astronautics). The predominant aim of the G.f.W. is to establish a committee of engineers and specialists whose task it will be to design a lunar rocket, at the same time without infringing Law No. 25 of the Military Control Commission, which authorizes theoretical research but bans all practical experiment. In January, 1950, the G.f.W. establishes the Hermann Oberth Medal, the first award of which was made to Alexandre Ananoff. Its Directive Committee is composed of : Honorary President, Professor H. Oberth ; President, Dr. Werner Schaub ; Representative and Director of the Technical Section, H. Gartmann ; Secretary, H. H. Kölle.

In the Eastern Zone H. Ruppe and Litterst set up an *Astronautische Arbeitsgemeinschaft* (Astronautical Study Group) in 1948 ; on April 26 of the same year, it is amalgamated with an analogous society at Lucka, taking on the appellation *Vereinigte Astronautische Arbeitsgemeinschaft* (United Astronautical Study Group), publishing a monthly bulletin "*Ad Astra*" since August 1, 1949. Its Directive Committee includes : Honorary President, A. Ananoff ; President, N. Litterst ; Scientific Directors, H. Ruppe and W. Strubbel.

AUSTRIA

In 1926, the *Österreichische Gesellschaft für Höhenforschung* (Austrian Society for High-Altitude Research) is founded in Vienna by Dr. von Hoefft, to be replaced shortly by the *Österreichische Gesellschaft für Raketentechnik* (Austrian Society for Rocket Technology) formed by the well-known technician G. von Pirquet and Zwerina.

After the war, two groups come into being : one in Vienna with G. von Pirquet, Dolezal, Schmiedel, and the other in Innsbruck, the *Österreichische Gesellschaft für Weltraumforschung* (Austrian Society for Interplanetary Research) founded in August, 1950. The latter has as President Dr. Ferdinand Cap and as Vice-President J. Rückert.

UNITED STATES

The *American Interplanetary Society,* founded in New York in 1930 by G. Edward Pendray and David Lasser, is the first astronautical society to be established in the

[1] The author of this article owes a great deal to K. E. Ziolkovsky for his initiation in this subject.

[2] We are informed that Engineer Albert Püllenberg had founded the *Gesellschaft für Raketenforschung* (Society for Rocket Research) and, between 1931 and 1934, the *Deutsche Versuchsanstalt für Raumfahrt* (German Experimental Station for Interplanetary Navigation). We publish this information with all due reserve owing to lack of precise reports concerning the two organisations.

Alexandre Ananoff, President of the Groupement Astronautique Français and Chairman of the First International Congress on Interplanetary Travel.

Professor Werner Schaub, President of the Society for Interplanetary Research.

Hans Joachim Rückert, Vice-President of the Austrian Society for Interplanetary Research.

A. V. Cleaver, Chairman of the British Interplanetary Society.

United States [3]. Since its foundation, it has gone over to practical realizations in constructing and trying out rockets analogous to those designed at that time by Nebel and Oberth at the *Raketenflugplatz* (Rocket Aerodrome) near Berlin. In 1934, the Society changes its name to *American Rocket Society* and its periodical *"Astronautics"* becomes the *"Journal of the American Rocket Society."* The Society is also interested in the military utility of rockets. Its New York Directive Committee is composed of : President, Mordon Gerla ; Vice-President, James Wheeler ; Secretary, James Nut, Jr.

The A.R.S. is affiliated with the commercial enterprise *Reaction Motors Inc.*, established in 1940, who undertake research on behalf of the Government ; it goes without saying that these are on the Secret List.

The A.R.S. has several affiliations ; the Southern California group, founded on February 17, 1949, has its seat in Los Angeles ; the Washington, D.C., group was established on March 7, 1949.

Amongst other associations interested in rockets, mention can be made of the *Cleveland Rocket Society ;* the *Peoria Rocket Society ;* the *Reaction Research Society in Glendale, Calif. ;* the *Detroit Rocket Society ;* the *Pacific Rocket Society ;* and finally, the US Rocket Society [4].

Prewar literature on space travel.

Present-day works on the same subject.

ENGLAND

In October, 1933, P. E. Cleator founds the *British Interplanetary Society* at Liverpool. Debates, lectures, visits of inspection as well as the publication of the *"Bulletin of the British Interplanetary Society"* (since January, 1934) render this Society one of the most active.

On October 27, 1936, the B.I.S. transfers its headquarters to London and Professor A. M. Low, D.S.C., assumes its direction. Its activities are terminated in 1939 only with the declaration of war.

The history of the British astronautical societies is somewhat obscure and, prior to the appearance of a sole national society, a considerable number of movements existed. Thus, in 1936, E. Burgess founds the *Manchester Interplanetary Society,* of which he becomes President, and which has published a periodical *"The Astronaut"* since April, 1937. In the beginning of 1937, J. D. Steward founds the *Paisley Rocket Society* in Scotland, which constructs and fires a number of rockets. In the same year, the *Leeds Rocket Society* is founded by H. Gateliffe and the *Hastings Interplanetary Society* by J. A. Clarke, both of whom affiliate with the B.I.S. in 1938.

In December, 1937, as a result of disagreement within the Committee of the Manchester Interplanetary Society, two of its members, T. Cusack and E. Burgess, form *The Manchester Astronautical Association,* which remains active during hostilities and publishes a periodical *"Spacewards."* K. W. Gatland founds *The Astronautical Development Society* at Surbiton which unites with the Manchester Interplanetary Society in 1944 to form *The Combined British Astronautical Societies,* which has four Sections in 1945, directed by Burgess in Manchester, L. Gilbert in London, G. Richardson in the Midlands, and G. Robinson at Tyneside. The C.B.A.S. publishes a review.

However, these "spontaneous" births have no effect other than to disperse efforts and hinder astronautical progress. For this reason, on September 25, 1945, those responsible for the various movements decide in common agreement to create a national society which will reassume the former title of *British Interplanetary Society.* Thus, since January 1, 1946, there exists in England a sole and unique society, that of London. For 1949-1950 its Administrative Committee is composed of : President, A. V. Cleaver ; Technical Director, L. R. Sheperd, Ph. D.'; Secretary, L. J. Carter, S.C.I.S. [5]

FRANCE

In France, the astronautical movement is initiated with the celebrated conference held by R. Esnault-Pelterie at the Sorbonne on June 8, 1927. The first important manifestation is the Astronautical Exposition held at the Palais de la Découverte in 1937.

On May 9, 1938, the Société Astronomique de France (French Astronomical Society) grants us permission to meet at its Observatory for a certain time "on a trial basis only." It would seem that this was conclusive, since the astronauts held their meetings there until September, 1939.

At the cessation of hostilities, the Société Astronomique de France withdraws its support from astronautics, maintaining that this had served no purpose other than the invention of lethal weapons ; in consequence, we approach the Aero-Club Universitaire et Scolaire de France (University and College Aero-Club of France) and, together with its President, M. Monier, we create an Astronautical Section on July 6, 1945.

On April 16, 1946, astronautics figures amongst the agenda of the National Congress on Aviation. In July, the first French astronautical bulletin *"L'Astronef"* appeared ; four issues only went into print.

In 1947, astronautics again is listed amongst the agenda of the National Congress on Aviation ; on July 6, on the initiative of M. Leveillé, we organise, together with H. Mineur, a permanent exhibition of astronautical developments at the Palais de la Découverte.

In the same year, the Astronautical Section of the A.-C. U.S.F. is incorporated with the Aeronautique-Club de France (French Aeronautical Club) and is designated as the *Groupement Astronautique Français* (French Astronautical Group). Its administrative body is composed of : President, A. Ananoff ; Secretary, M. Budry ; Treasurer, M. Gras. The *"Astronef"* is to appear as a quarterly from September 30th on, notably the occasion of the First International Astronautical Congress.

SPAIN

The first Spanish society is now being formed in Madrid. Its founder, Tomas Mur Vilaseca, a Government mining engineer, has been able to interest other engineers in the subject.

NETHERLANDS

At present there exists no astronautical movement in the Netherlands. There was, in 1934, the *Nederlandsche Raketenbouw* (Netherlands Rocket Manufacturing Company) at The Hague, founded by Gerard A. G. Thoolen for the purpose of designing and experimenting with explosive-powered rockets for mail carriage.

CANADA

An astronautical society exists in Ontario, namely the *Canadian Rocket Society,* founded in 1948.

ARGENTINA

The *Sociedad Argentina inter-planetaria* (Argentine Interplanetary Society) was established a number of years ago ; headquarters is at Buenos Aires. President, Teophil M. Tabanera, Professor at the University of La Plata ; Secretary, R. Martinez de Vedia, engineer.

AUSTRALIA

In 1936, an *Australian Rocket Society* existed in Brisbane, whose chief interest was mail rockets. The latest society at this date, founded in Melbourne in 1941, bears the same name.

THE FIRST INTERNATIONAL ASTRONAUTICAL CONGRESS

What is to be learned from this survey ? That the general tendency is the amalgamation of the various smaller movements, originating by virtue of the progress realized during the war, into a single large national society.

Notwithstanding, differentiation must be made between societies with an official character such as the *American Rocket Society,* or the *Reaktivnoia Sekzia* of the USSR, whose chief preoccupation is rockets solely, and astronautical associations in the proper sense of the word. The former are engaged chiefly in the immediate applications of auto-propulsion, whereas the latter have an interest in far larger perspectives and undertake investigations concerning all problems touching on cosmic navigation. We emphasize this particular nuance simply because it does exist. Nevertheless, it is fundamental to realize that even though the astronauts reproach the military rocket technicians with following an aim which is too much "earth to earth," they know full well that they cannot remain indifferent to the progress accomplished by these latter with the important financial means allocated to them. We merely request those whose interests are primarily astronautical not to forget that there are also the technicians and those whose interests are primarily technical not to forget that there are also the astronauts.

These latter met for the first time in Paris from September 30th to October 2nd. More than ten countries were represented at this meeting. Even though the Congress does not give birth to an *International Centre for Astronautical Study and Research,* this first world congress will nonetheless mark an important milestone towards the achievement of interplanetary navigation.

[3] It would seem that in 1918 there existed a Rocket Society of the Academy of Sciences. Owing to lack of precise information, we cannot confirm this.

[4] It should be recalled that there was a *Yale Rocket Club* in 1935, an *American Institute for Rocket Research* in 1936 at Chicago, and a *Westchester Rocket Society* in 1936.

[5] In addition, there has been a *Rocket Club* at Cambridge since 1941 and a *Rocket Research Society* since 1940.

USS "Norton Sound," a floating laboratory for remote-controlled rocket trials.

US Navy Fires into the Ionosphere

In the middle of May of this year, the American special tender "Norton Sound" once again sailed out of its Californian harbour Port Hueneme. Course was set for the Christmas Islands located in the Pacific Ocean near the equator. Apart from the normal ship's crew, a group of scientists, technicians and representatives of the US Navy were on board.

As a supply ship for marine aircraft of the US Navy, the "Norton Sound" formerly had a very uneventful existence. By virtue of its conversion to a floating laboratory for experiments and trials with remote-controlled rockets, its destiny was changed overnight. Throughout the last few months this ship has even received intense publicity in the press and radio. Amongst other reports, mention has been made of a 21-day cruise in the Bay of Alaska during September, 1949, on which a number of remote-controlled projectiles of the type "Aerobee" were fired.

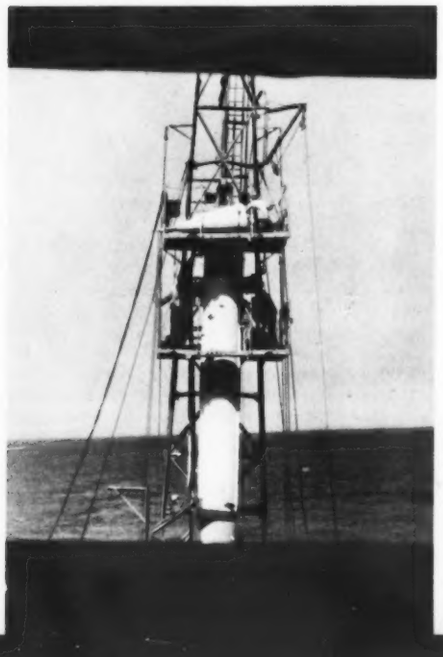
During its reconstruction the "Norton Sound" was fitted out with a firing ramp for launching rocket projectiles on the stern deck, equipped for this purpose with heat-resistant steel plating. An observation tower for the take-off of the rockets was likewise installed at the rear end of the superstructure. Finally, the forward deck was remodelled so as to provide a take-off and landing space for helicopters. It can hardly be assumed that the helicopters are merely for the purpose of allowing the crew, nostalgic for a vacation on terra firma, to avoid the discomforts of climbing down into a rocking rowboat. It is far more probable that they are operated for the purpose of arriving at the points of contact of the return rockets as quickly as possible. Whenever it is at all feasible, attempts will be made to salvage at any rate the highly expensive rocket heads from the waves. In certain types they are provided with parachutes for slow descent, after the head has become separated from the remainder of the rocket by automatic release. Of course, the evaluation of the trials does not depend upon the relocation of these heads ; the instruments with which the rocket itself is fitted out transmit their recordings and observations by means of ultra short waves to a receiving station on board the ship.

Several purposes are simultaneously served by the rocket ascents from the deck of the "Norton Sound." Primarily, certain important additional experience is thus obtained for trials on land. For the operation of a floating firing base permits firing with a considerably smaller angle of elevation than is the case on land owing to security regulations normally applied. For this reason, as early as two years ago, a number of V2 rockets constructed in the USA were fired from the "Norton Sound." A further purpose is also the training of crews for the operation of rocket projectiles at sea. It can be assumed that the US Navy anticipates installing her units—surface ships and submarines—with firing ramps for remote-controlled projectiles, to serve in combat against aircraft and naval attacks as well as land targets. Numerous firing trials, in part with rockets now in mass production, are now being carried out in the USA ; new types for the most varied kinds of operation are under development.

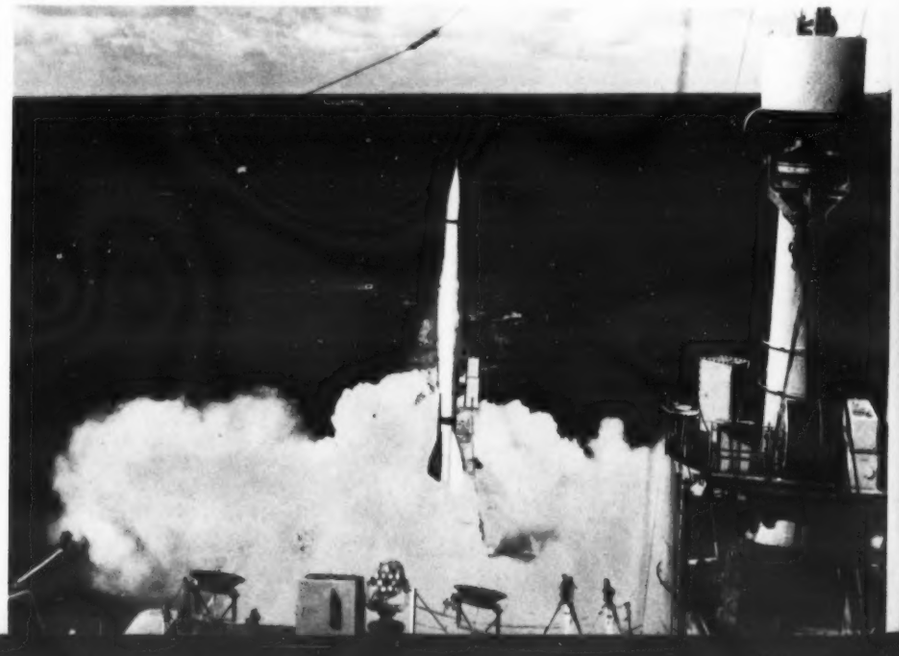
The value attributed by the US Navy to these trials is apparent from a statistical report published more than two years ago. This showed clearly that more financial means are allocated for the research and development of remote controlled projectiles than for any other project. Furthermore, it was stated that a new class of submarines faster and more adapted to the firing of remote-controlled missiles, should be created. Finally, a new class of submarine vessel, installed with radar for the purpose of guiding fighter aircraft and steering remote-controlled weapons, will be put into operation in all probability.

This time, a single rocket of the "Viking" type was fired in the waters about the Christmas Islands. Special notice should be taken here of the fact that the "Viking," produced by the Glenn L. Martin Co. Aircraft factories in Baltimore, is a purely experimental prototype, and that only ten such will be produced and fired. The experience gained at each trial is taken into account in the construction of the subsequent projectile. In this manner, the US Navy hopes to develop a remote-controlled projectile superior to the German V2. So far, the record altitude of 185 km obtained by the V2 has not yet been surpassed. Nevertheless, the last "Viking" fired from the "Norton Sound" reached an altitude of 170 km and thus established a record for American single-stage rockets. With this, a further contribution has been made to a research program whose aim, on the one hand, is the investigation of the ionosphere (temperatures, atmospheric densities, cosmic rays), and on the other hand the development of high-performance remote-controlled projectiles.

View from the observation tower on the firing ramp. A "Viking" rocket is being prepared for firing.



A "Viking" rocket taking off for flight into the ionosphere. A projectile of this type recently attained an altitude of more than 170 km.



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Presentation of Arms in the East

Soviet Russia's Modern Airforce

BY XY, MOSCOW

There is no such thing as an "old Russian hand"; there are merely those with varying degrees of unenlightenment...

Is the Soviet Union a menace to world peace? Its own diplomacy and those in a position to speak for the countries behind the Iron Curtain would reply in the negative. Western diplomacy sees considerable cause for worry in the accumulating stocks of Russian armaments, in the Russian industrial potential and in the veil of secrecy drawn over all Soviet undertakings. The Soviet empire undoubtedly is a well-forged unity. Its present military strength can perhaps be compared only with that of the Third Reich. And a significant rôle is played in this display of power by the Red Air Fleet.

The major part of the Russian Air Force—despite the attribution of strategic bombing formations to the Navy—is still a component of the Army and hence a part of that renowned steamroller, proverbial since World War I. Should the worst occur, the Western Powers will be able to delay the advance of Soviet Russian tanks only if they can also hold in check the Red Air Force.

From this somewhat simplified statement, however, it can be seen how important is the correct estimation of the quantity, quality and aims of the Russian air power. And the aims of the Western Powers? First and foremost, the creation of an air force equal and even superior to that of the USSR.

With the Friendly Collaboration of the West...

During the last war, the main Soviet production effort was concentrated on the mass production of types designed for immediate military operation and of strictly orthodox and even obsolescent design. In many cases, simplicity of production procedure took precedence over fighting efficiency, though these relatively few types, operated *en masse*, were able in the main to fulfil their task successfully.

Nevertheless, when, towards the end of the war, and especially after it, the newest types of the German *Luftwaffe* fell into their hands, and a number of aircraft of the Western Allies landed behind the Soviet front, the Russians were forced to recognize to what extent their own air armament was behind the times. In point of fact, the Red Air Force had, by the end of the war, sunk—even numerically—to complete insignificance.

This was the turning point. Five years of intense research and development—with the inestimable collaboration of German engineers and equally inestimable aid of the British aircraft industry—have sufficed to make the Soviet air force one of the two most powerful in the world.

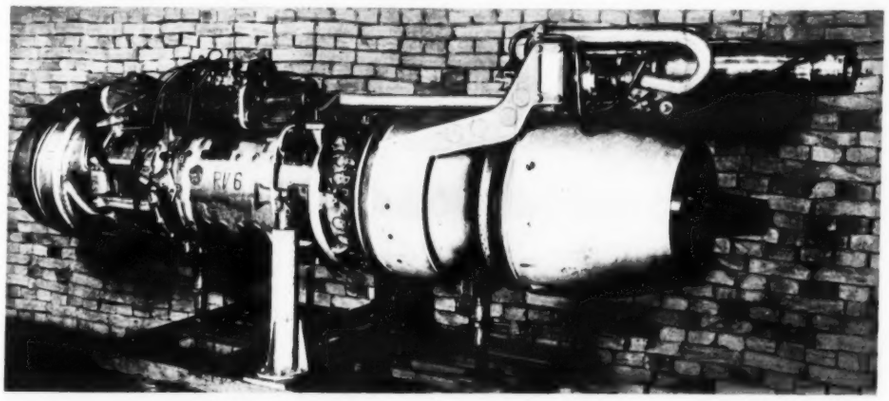
This air arm can perhaps be regarded from the purely qualitative point of view as still transitional. However, the fact remains that large-scale production of modern jet types has now begun. True, the introduction of the new power plant and highspeed aerodynamics, together with the necessary refined equipment and electronic apparatus, has been a source of immense difficulties to the Russians. Nevertheless, the USSR's latest mass-produced swept-wing fighters and jet bombers are in all probability able to acquit themselves well against those of Western powers. And even though part of their formations are equipped with reciprocating-engined aeroplanes of war-time design—is this not equally applicable to the service flying equipment of the Western Powers? And these more obsolescent types will in the meanwhile provide a most welcome "second combat reserve." At any rate, in the event of an outbreak of hostilities, the newer types of Soviet aircraft would so handicap the Western Powers that they would have hardly anything left to oppose to such reserve formations.

The combat strength of the Soviet Air Force is today estimated by the Western Powers "officially" at 15,000 to 20,000 first-line aircraft. These, however, merely form the nucleus of an incomparably larger potential air strength, as the whole Soviet sphere of influence has been made "airminded" to an unprecedented degree. This has been accomplished to no small extent—as in the case with Goering—by the mass formation of pilots, aircraft and aero engine technicians, who are recruited practically from the kindergarden directly to the aviation training schools and the gigantic DOSAV organisation [1]. This latter gives elementary training in aircraft model making, gliding and later powered flight, parachuting, etc., at the same time promoting competition in aeroplane design. Hence, in the event of a new war, the Soviet Union or rather its air arm would hardly be likely to suffer from a shortage of personnel!

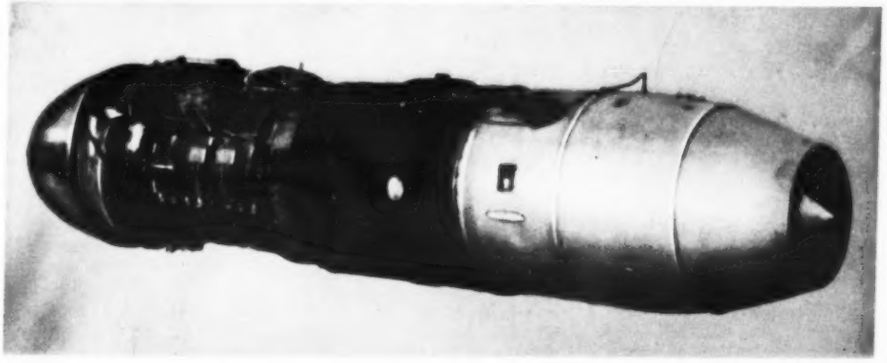
In all probability, however, a more important bottleneck for the Soviet aeronautical industry lies in the procurement of tooling for the manufacture of aircraft, aero-engines and accessory equipment.

[1] Dobrovolnoye Obstshyestvo Szodyeistviya Aviazya or Union of Voluntary Aviation Assistants.

The **BMW 003 turbojet**—here fitted with a BMW 718 auxiliary rocket unit (for take-off) and hence designated in Russia as **M-003 R**—had an output of 1,760 lbs. (800 kg) static thrust at 9,800 r.p.m. plus a 2,200-lbs. (1,000-kg) rocket thrust, at the end of the war. Construction: 7-stage axial-flow compressor, annular combustion chamber, single-stage turbine. Meanwhile, its static thrust has been increased to about 2,750 lbs. (1,250 kg), and a further development, the **M-018** for a 7,700-lbs. (3,500-kg) thrust, with a 12-stage compressor and 3-stage turbine, is being subjected to trials.



The **JUMO 004 turbojet** (Russian designation: **M-004**) attained in Germany a 1,980-lbs. (900-kg) static thrust at 8,900 r.p.m., but has probably been increased meanwhile to a thrust of 3,080-3,960 lbs. (1400-1800 kg). Construction: 8-stage axial-flow compressor, six combustion chambers, single-stage turbine. The further development, designated **M-012**, shows an 11-stage compressor, eight combustion chambers as well as a 2-stage turbine and develops 5,950 lbs. (2,700 kg) static thrust at 6,000 r.p.m.



The first Russian jet fighter, the YAK-15 (with tail-wheel landing gear), and its improved version, the YAK-15B (with nose-wheel landing gear), were developed from the extremely manoeuvrable **Yakovlev YAK-9** mixed-construction fighter by replacing its piston-engine with an M-004 centrifugal-type turbojet underslung below the fuselage.

During World War II, Soviet manufacturing capacity was far out-distanced by the combined British and American output. And today ? Whereas the Americans and British reduced their production to a small fraction of their war-time capacity immediately upon the cessation of hostilities, and whilst the French or Italian aircraft industry as yet still have to be created anew, the Russians have been able to expand their own aircraft production considerably. The first step was mass purchasing of tooling and production machinery in Western Europe and overseas, to be followed by the installation of the factories themselves, and finally production.

If a comparison is made between the older Russian designs and those of today, however, it should not be overlooked that Russian engineers live in an entirely different world to that of their Western colleagues. So long as they enjoy the benevolence of their administrative and political superiors, they can rely on unlimited support and dispose of first-class research facilities, windtunnels, and so on. On the other hand, if they are unlucky enough to suggest any innovation which proves to be either unsuccessful or not in line with official views, they "lose face"—to employ an Easternism—and even their liberty. This naturally results in a throttling of originality and decision.—One consequence of this policy has already been the crisis which confronted the Soviet Air Force at the end of the war. After the cessation of hostilities, frantic efforts were made to acquire German research material and technicians, British and German turbojets, modern equipment, and so on, in order to match the technical superiority of Western material.

Power Plant, Armament, Equipment

A further difficulty definitely lay, and in all probability still lies, in the question of the performance and reliability of the Russian *gas turbine engines*. It is almost certain that not a single turbojet now being produced in Russia is of purely Soviet design. Either German axial-flow turbojets developed by BMW, Junkers and Heinkel-Hirth, or the centrifugal compressor types such as the Rolls-Royce "Nene" and "Derwent," supplied by the British Government, have been used as prototype bases.

At any rate, during the period from 1945 to 1948 the majority of new Soviet aircraft were powered with axial-flow engines, and these to all appearance have not proved to be very reliable. In fact, a number of prototypes, including a promising four-engined bomber, are still not in service in quantity. It was only with the delivery of the more advanced Rolls-Royce power plant that the position probably underwent a decisive change. The sweptback fighters now in quantity production—notably the MIG-15 and LA-17—certainly appear to be equipped with centrifugal compressor units. Newer types, however, now going into production—notably in the attack bomber category—are actually fitted with axial-flow turbojets. From this it could be inferred that operational reliability has now also been reached in the case of axial-flow engines.

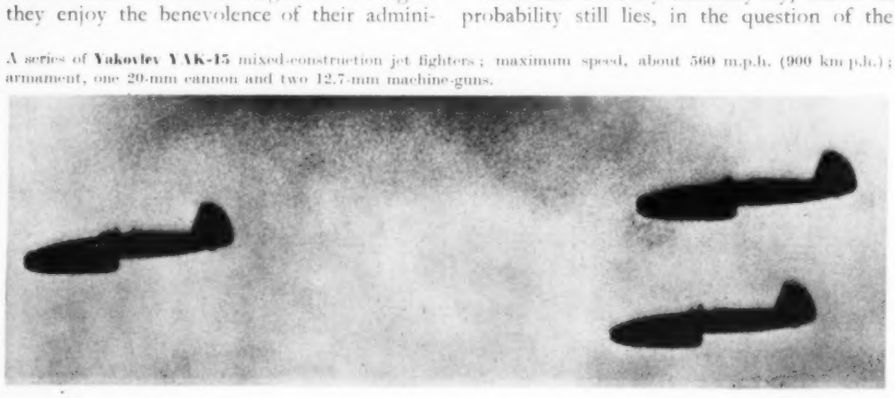
In the field of *rocket power plants*, the Russians have their own experts. These have been given complete freedom of action and German technicians and German research data have been placed at their disposal. A considerable amount of experimental work on *rockets*, as well as on *pulsejets* and *ramjets*, is now going on. *Afterburning* as power boost for jet aircraft is also in development.

Russian *aircraft armament* is of high quality, the significant feature being the use of very large calibers (40 mm and 53 mm) for ground target attack. Moreover, the development of rocket projectiles for air-ground assault has suffered no delay. The standard armament of bombers and fighters includes 20-mm and 30-mm guns. True, some of the more recent fighters carry only two cannon, but there is a definite risk that the Soviet weapons will outrange the 12.7-mm or 20-mm machine-guns of Western Union aircraft.

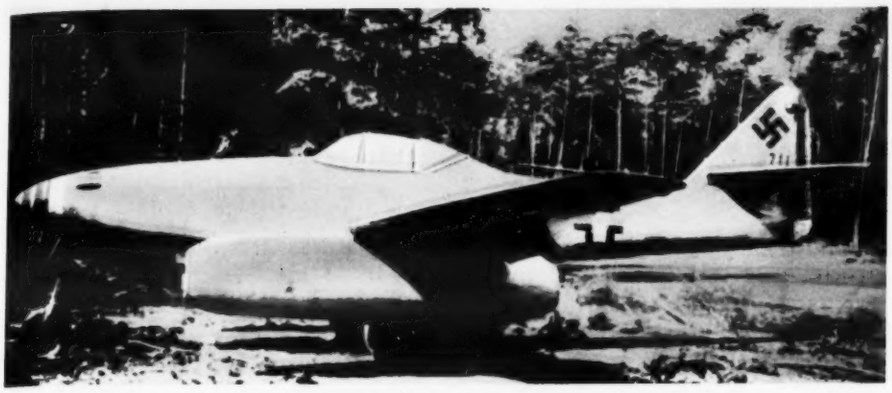
Finally, a whole host of new *equipment problems* have been encountered : ejector seats, heating, oxygen systems, etc. had to be developed from scratch. By the end of the war, the Soviet fighter pilot's personal equipment was composed of the most essential items only ; of primary importance was that "his crate flew." Today the ejector seat is standard equipment for all more recent Russian high-speed single-seater fighter aeroplanes. But G-suits and other "luxuries" will probably be neglected until they become absolutely indispensable. Soviet pilots are tough and can stand a great deal.

Radar technique is said to be merely beginning in Russia. It is true that some system of radar-coordinated night defense exists and that night fighter aircraft with airborne radar are in service. However, the reliability of Russian radar, as of Soviet wireless navigational and instrument-landing apparatus, is problematic. For instance, civil transport aircraft still navigate their way about the Soviet Union by

A series of **Yakovlev YAK-15** mixed-construction jet fighters ; maximum speed, about 560 m.p.h. (900 km p.h.) ; armament, one 20-mm cannon and two 12.7-mm machine-guns.



About the same time, the **MIG-9** all-metal jet fighter (Mikoyan-Gurevich), with two M-003 centrifugal-type turbojets below the fuselage, appeared in the Russian sky ; maximum speed, more than 530 m.p.h. (850 km p.h.) ; armament, one 43-mm and two 20-mm cannon.



The German **Messersehmitt Me 262** jet fighter was able, with two JUMO-004 turbojets, to attain horizontal speeds of more than 530 m.p.h. (850 km p.h.); climbing speed 3,900 ft.p.min. (20 m.p.sec.) armament, four 30-mm cannon.

The Soviet **Lavochkin LA-15** strongly recalls the Me 262, but is powered with BMW (M-003) units.

map-reading, and it is highly dubitable whether all-weather operation in the Western sense of the word is possible within the Soviet Air Force. But does the threat of heavy casualties mean a great deal to the Russians ? Vital air missions will be flown even in bad weather, and to this extent the Soviet lack of all-weather electronic equipment will be compensated, at least in part. Beyond all doubt, the next two years will bring about—with reliance on the German, British and US patterns—considerable progress in this field as well.

Jet Fighters

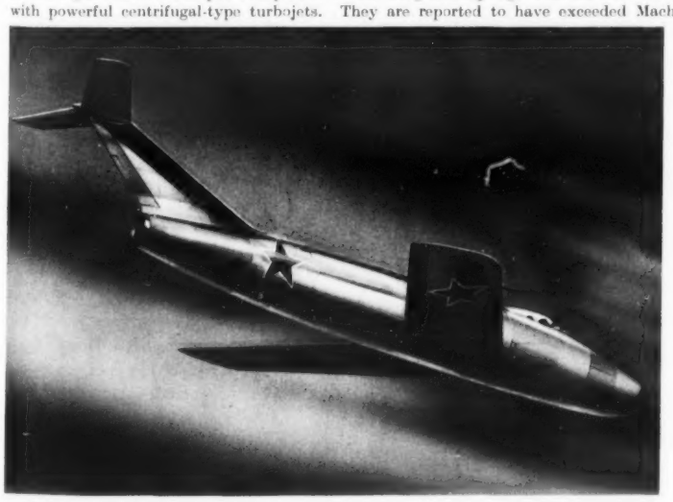
During the last five years, Soviet designers have been particularly prolific in the production of single-seater fighters, more of which have appeared than any other combat type. It is obvious that the immediate post-war need of the Soviet Union was jet-propelled fighters. This explains a certain crudity in their early designs, which were obviously developed with the greatest haste. Nevertheless, these early jet fighters provided the means by which a reserve of jet pilots could be trained against the day when better aircraft would be rolling off the assembly lines. At the same time, they provided the Government with new implements for domestic and foreign propaganda.

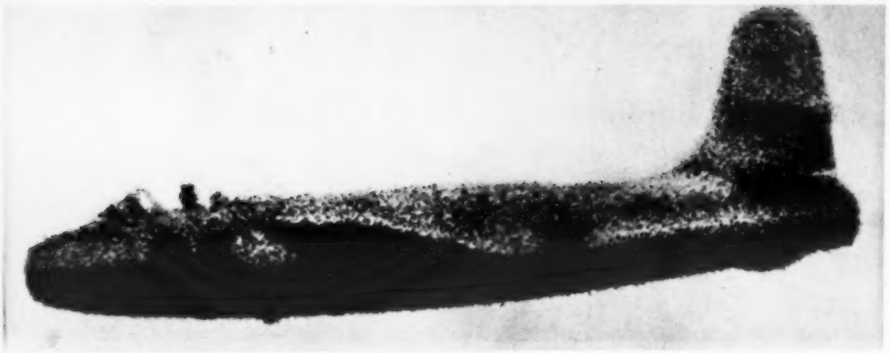
The first jet fighter to be put into service, the *YAK-15* (designed by Alexander Yakovlev), is today well known. During the Aviation Day Flying Display at Moscow in 1946, the YAK-15 was first introduced to the general public by flying over the Tushino Airfield. Originally planned as an interim type for training purposes only, the YAK-15 is an example of the haste with which the design was prepared, as previously mentioned : tubular steel fuselage and mixed steel and wooden wings (steel sparts, wooden ribs, plywood skin) of the YAK-9 piston-engine fighter were taken over with hardly any modification. Only the forward fuselage section was redesigned to accommodate an underslung Jumo 004 turbojet. In order not to delay production, and possibly because Yakovlev at that time had no experience with modern nose-wheel undercarriage, the tail-wheel landing gear of the YAK-9 was retained, the stroke of the main wheel legs merely being increased to allow adequate ground clearance for the underslung turbojet. As a consequence, pilot visibility for take-off is extremely poor. Nonetheless, the YAK-15 has proved to be a very useful interceptor fighter. With a span of little more than 32 ft. (10 m), the type has shown flight characteristics equally as good as those of its precursor, the YAK-9 piston-engined fighter, which, as may be recalled, could out-manoeuvre the very manoeuvrable Focke-Wulf Fw-190. On the other hand, its armament—a twenty-millimeter cannon and two 12,7-mm machine-guns—was, according to modern standards, as deficient as its armour plating. For it is the Russian practice to reduce armour to a minimum in the interest of performance and flight characteristics, despite the greater danger to the pilot. Thus, with a power plant the output of which then amounted to only some 2,200—2,500 pounds thrust, the YAK-15 attained a maximum speed of approximately 560 m.p.h. or 900 km p.h.

A further development of the YAK-15 is still in production. Owing to lack of knowledge as to its actual designation, it will be listed here as the *YAK-15B*. Produced both as a two-seater advanced trainer and as a single-seater fighter, the YAK-15B is powered with a later Russian derivation of the Jumo 004 (developed by M. B. Chelomey) producing a thrust of about 3,000 lbs. In contradistinction to the basic type, the YAK-15B has a fully-retractable nose-wheel landing gear whereby the tail wheel hitherto fitted is replaced by a small tail bumper. The characteristic curved outline of the vertical tail surfaces seen on all Yakovlev fighters has given place to more angular contours. The second cockpit for the trainee is forward of that of the instructor and has good visibility.

About the same time that Yakovlev was preparing his YAK-15 for production, Miekhael E. Gurevich and Artem I. Mikoyan were

Two versions of the Russian **sonic research aeroplane :** That at the left is characterized by a central air intake and an only slightly trapezoidal swept-back wing ; the version at the right shows a sharper sweep-back of the wing leading-edge with an almost straight trailing-edge, and "elephant ear" air intakes. Both versions are probably fitted with powerful centrifugal-type turbojets. They are reported to have exceeded Mach 1 (in power dives ?).



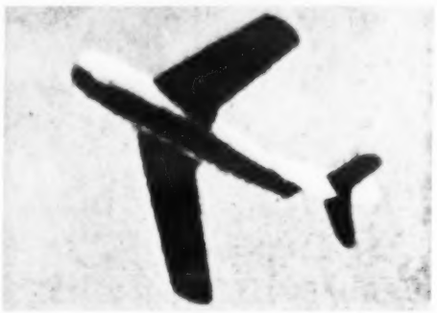


The **Yakovlev YAK-17** ("Red Thunderjet") jet fighter now in production shows a central air intake at the fuselage nose a centrifugal turbojet, and a conventional straight wing and tail assembly.

working on an all-metal mid-wing monoplane, the *MIG-9*, powered with two BMW 003 turbojets slung under the fuselage ; however the "BMW" is not retained in the Russian designation. Evidently the Russians found this "pod-and-boom" lay-out attractive for two reasons : firstly, with jet unit low and empennage high, it was possible to have a short jet pipe, and secondly, because the turbojets then available, running time of which amounted to only about 30 hours, could be easily changed. As soon as better turbojets became available, Yakovlev—as well as Mikoyan and Gurevich as will be seen later—altered their power plant lay-out. In resumé : Both the YAK-15 and the MIG-9 represent a transitional phase.

Like the majority of Russian fighters, the MIG-9 is a multipurpose aeroplane and combines the task of a medium-altitude interceptor with that of a ground-attack fighter. Heavily armed—a 43-mm cannon and two 20-mm or 30-mm cannon together with two 12.7-mm machine-guns—the MIG-9 is particularly suitable for the latter task. The most recent versions of the MIG-9 are probably powered with M-003 turbojets developing a higher thrust, with a total of probably 5,000 lbs. for the two ; these have been designed by A. D. Shvetzov. At ground level, the MIG-9 probably attains a maximum speed of more than 530 m.p.h. or 850 km p.h. That the design has found approval is indicated by the fact that its constructors were awarded a Stalin Prize (First Class) in 1947.

Another important designer, Semyon A. Lavochkin, appears to have had rather less success in the period immediately following upon the war than his compatriots mentioned above. His first twinjet fighter, the LA-15, followed hard on the heels of the MIG-9, but teething troubles have precluded large-scale production. Purely externally, the *LA-15* bears a strong resemblance to the Messerschmitt Me 262, though it was powered with two (BMW) M-003 turbojets (in place of the Jumo 004 of the Me 262). If one can go by its armament—30-mm and 20-mm (or 23-mm) cannon—the type seems to have been designed for close ground-support work. Comparable in size and power to the Me 262, the LA-15 should probably attain the same performance as the Me 262, i.e. 530 m.p.h.



Jet fighters of the **MIG-15** type are today appearing over Eastern Europe in large formations : Mid-wing monoplane with a 35° sweep-back, strongly swept-back tail unit, centrifugal-type turbojet housed in the fuselage. The fighter is characterized by outstanding manoeuvrability and extreme speed (685 m.p.h. or 1,100 km p.h. ?).

From their very first investigations, the Russians soon recognized that sonic speeds could be attained only with swept-wing aircraft. In addition, they perceived that specialized single-purpose fighters—radar-equipped night or all-weather fighters, target-defense interceptors, etc.—were indispensable to the Soviet air force, if it was to achieve technical parity with Western air power. With this, the epoch of fighters for multi-purpose operation came to an end.

Then, in May 1947, came the first reports of successful flights of Russian experimental aircraft at Mach 1 and over. As usual, the announcement was viewed sceptically by the British and American press. This scepticism, however, diminished somewhat when a *swept-wing high-speed research aeroplane* appeared in the 1948 May Day Air Parade over Moscow. This mysterious aircraft has frequently been described as a variant of the German DFS 346, though the latest photographic evidence does little to support this contention. True, it is common knowledge that the Russians took special care of the Siebel firm at Halle, where the DFS 346 was to have been constructed, but this latter fact and a certain similarity of wing and empennage design are not sufficient in themselves to support this conjecture.

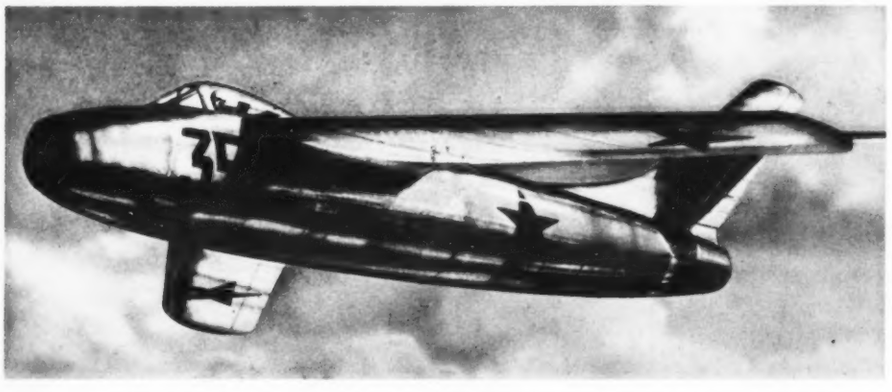
This experimental type was next followed by a production model with conventional wing which, owing to its similarity to the American F-84, has been referred to as the "Red Thunderjet" and is probably designated as the *YAK-17*. The design shows that Yakovlev was not slow to assimilate Western jet fighter trends. The YAK-17 is fitted out with a single centrifugal-type turbojet and is of simple, straightforward construction. The American F-84 is only externally similar, since the Russian type's power plant is less powerful, whilst range and speed are likewise inferior. But the YAK-17 is perhaps more manoeuvrable. Despite the nosewheel landing gear, a large tail bumper acting as a safeguard against damage from tail-down landings has been fitted. According to certain reports, a version with swept surfaces has been produced.

Recently, a further conventional-wing fighter, the *MIG-11*, designed by the Mikoyan and Gurevich team, has made its appearance. Appreciably more rotund than the MIG-9, this aircraft has apparently not been placed in production, probably owing to greater enthusiasm shown by Russian research in the meanwhile for sweptwing types. The MIG-11 has a shoulder wing of small span and is probably powered with an axial-type turbojet.

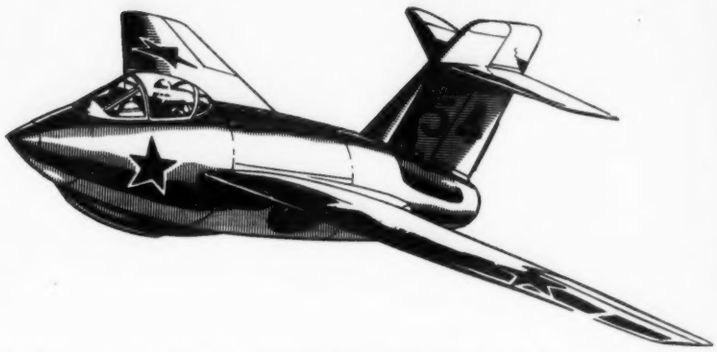
For some time, reports of *formations of swept-wing fighters* seen flying over Russia have added to the confusion concerning the Red Air Force. These have now been officially confirmed and it can be assumed that two such types have in fact been supplied in large quantities to the Soviet Air Force.

The first of these, a further Mikoyan-Gurevich design, is the *MIG-15*, which must be regarded as an absolutely advanced construction. A description and first photo are to be found in No. 8-9 of this Review. It may be briefly recalled that the type is powered with a centrifugal-type turbojet designed by Chelomey, the Russian development derived

The **Lavochkin LA-17** jet fighter, a swept-back shoulder-wing monoplane, is also in mass production ; likewise powered with centrifugal-type turbojets, it probably has flight characteristics and performance equal to that of the MIG-15.



The **Me 163 rocket fighter** (or Ju 248) of A. Lippisch was operated for ground-target defense in Germany : swept-back wing with elevons, retractable landing skid, jettisonable undercarriage for take-off ; maximum speed about 620 m.p.h. (1,000 km p.h.) ; climb to 33,000 feet (10,000 m) in three minutes.



The Russian version of the Me 163, the **Yakovlev YAK-21** rocket fighter, is provided with a retractable undercarriage and with an elevator unit. With a speed of 685 m.p.h. (1,100 km p.h.) and a climbing speed of 12,000 ft.p.min. (60 m.p.sec.), the YAK-21 is an ideal weapon for defense against the Convair B-36 bomber.

from the Rolls-Royce "Nene." Conservative estimates assume that the MIG-15 is, it is true, faster than the majority of British jet fighters, and in all probability likewise surpasses the American F-80 and F-84 types, but leaves much to be desired with regard to range.

The second, probably developed simultaneously with the MIG-15 for mass production purposes, is the *LA-17* designed by Lavochkin. Whereas the MIG-15 is a mid-wing monoplane, the LA-17 is a shoulderwing type, probably powered with a similar turbojet and showing like performance. As compared with the MIG-15, it shows a somewhat sharper wing sweep-back, a longer fuselage and a more graceful fin and rudder.

These two last types are apparently the new main units of the Russian fighter command.

Rocket Fighters

Russian war booty included a new type of German target-defence interceptor, whose quality and number sufficed both for theoretical investigation and practical trial. Included in this booty were also the engineers who designed it, the factories in which the airframes were produced, and finally the plant in which the rocket-engines were manufactured. We refer to that rocket fighter of the German Luftwaffe, initially designated Messerschmitt Me 163, later Junkers Ju 248, and meanwhile designated in the Soviet Union as the *YAK-21*. Design and development were the responsibility of A. Lippisch, while Messerschmitt constructed the first prototype and later turned it over to Junkers ; the power plant was produced by Walter in Eberswalde near Berlin. In operation with the German airforce, this aeroplane proved as dangerous to the enemy as it was on the other hand to its own pilot : Climbing to 33,000 feet (10,000 m) in three minutes, its flight duration was only 6-12 minutes so that it was an easy prey for American escort fighters once it began gliding down to land.

At any rate, the Russians very soon recognized the type's inherent possibilities and as early as two years ago Lieutenant-Colonel G. A. Tokaev, one-time member of the Soviet Air Force's investigation staff in Germany who fled to Great Britain, reported that his compatriots had undertaken the further development of this interceptor for target defense. Meanwhile, it is said to have exceeded the sonic boundary and to be reserved as a target-defense interceptor about Moscow and in the heavy industrial areas west of the Urals. Reportedly, the formations which have been equipped with this fighter are responsible for the internal air defense of Russia (Protovovozdushnaia Oborona).

Externally, the YAK-21 differs from its German predecessor in having a tail plane mounted high on a large-area fin, as well as an undercarriage probably used for take-off purposes only, since the landing-skid of the Me 163 has been retained. The Walter HWK 509C liquid-fuel rocket engine is said to develop some 4,500 lbs. (2,000 kg) thrust, an improvement from its former 3,700-lb. thrust ; flight duration probably does not exceed 15 to 20 minutes. With a maximum speed of around 670 m.p.h. (1,080 km.p.h.), a climbing speed of approximately 12,000 ft. per minute or 60 metres per second—rivalled only by the newest British experimental "Sapphire-Meteor" fighter—the YAK-21 is an ideal weapon of defense against the B-36 bomber.

. . . Jet Bombers

It should once again be recalled that Russia's aircraft industry has tended to concentrate rather on the production of jet fighters than on that of jet bombers. At any rate, so far . . . Nevertheless, the Red Air Fleet has always been an enthusiastic disciple of both friend and enemy, and hence it is justified to state that a more powerful strategic bombing force is now being built up.

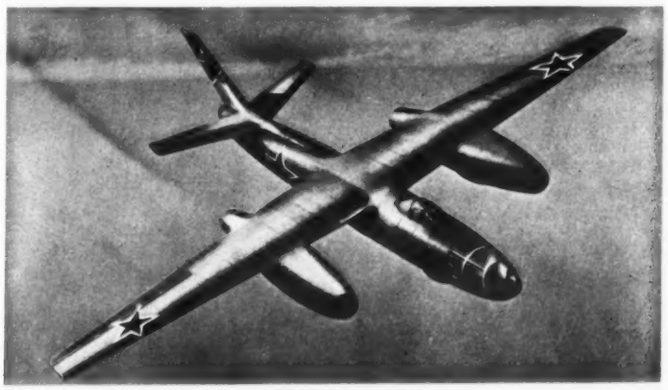
The dean of Soviet bomber designers is and remains A.N. Tupolev, whose stormy career cannot be discussed here in detail.

His first jet bomber was developed from the TU-2, was probably designated as the TU-8 and first appeared on the horizon in 1947. Wing and tail assembly do not differ from its TU-2 precursor, though the fuselage was somewhat lengthened. In addition, the tail wheel of the TU-2 was replaced by a tricycle undercarriage.

In any case, the type was only an interim development, from which the TU-10, which made its debut in May 1950, was to be derived. This is the Soviet counterpart of the British "Canberra" jet bomber. The TU-10 has a wing span of 70 feet (21.5 m) and is fitted with two M-003 or M-004 axial-flow turbojets thrust of which has meanwhile been

The **Tupolev TU-8** twin-jet bomber was derived from the well-known TU-2 light bomber.

A **Tupolev TU-10** twin-jet bomber with axial-flow turbojets (M-003 or M-004), each producing a static thrust of 3,950 lbs. (1800 kg) ; machine-gun turret in the tail.



The **Arado Ar 234 C** four-jet bomber (four BMW 003) was also included in the war booty of the Red Army : Maximum speed, 545 m.p.h. at 20,000 ft. (875 km p.h. at 6,000 m).

The **Ilyushin IL-16** four-jet bomber (with tail gun turret) is the counterpart of the North American B-45 "Tornado."

increased to 4,000 lb. (1,800 kg). With a circular-section fuselage, the bomber has a square-cut wing. Equipped as a three-seater, the cabin is believed to be pressurized. The TU-10 is said to be intended for high-altitude operation as well as for ground support. It differs from the "Canberra" in that it appears to have provision for a tail gun post. Data concerning gross weight, bomb load and fuel reserves are equally as difficult to obtain as those for the comparable British type. Speed probably amounts to about 520-540 m.p.h. (840-870 km p.h.).

What about four-engined jet bombers ? An aerial photo shown here proves their existence. The well-known designer Ilyushin developed the *IL-16* four-jet bomber, existence of which has been known since 1947, and whose appearance in general is very much like that of the German Arado 234 or the much more advanced North American B-45 "Tornado."

To what extent, however, large-scale production of this big warplane has been initiated, belongs to the sphere of conjecture. In the meantime, the Russian TU-4 "Superfortress" (American B-29) continues to form the backbone of the Red strategic bombing force.

*

Every compilation is of necessity dry and tedious. Even one concerned with a subject so enthralling as the strength of the Red Air Force.

The purpose of this report has been to show that since 1945, the Soviet armed forces, in addition to gigantic armoured and innumerable infantry divisions, have been able to create an air force numerically second to none in the world, the quality of which should no longer be underestimated.

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Presentation of Arms in the West

Farnborough 1950

On the occasion of the 11th SBAC Display, the exhibition of the Society of British Aircraft Constructors held from September 5th to 10th in Farnborough, approximately 14,000 visitors from all countries "in front of the Iron Curtain" were able to inspect *58 aircraft of various types* together with the *most recent turboengine developments* and *aeronautical equipment*. It was the most modern apparatus that the British industry can show and offer ; military aircraft predominated.

New swept-back fighters

As compared with the USA, the development of swept-back fighter aircraft began relatively late in Great Britain. It is scarcely two years ago that flight trials with the Vickers-Supermarine 510—swept-back wing and elevator unit—were started. Shortly afterwards, Hawker likewise began testing their P.1052 experimental swept-back type. Apparently, both firms were satisfied with the trials and for the first time this year two developments derived from these types were shown in public : *Vickers-Supermarine 535* and *Hawker P. 1081*. They were the chief item of interest in the display.

Both the Supermarine 535 and Hawker P.1081 are powered with a Rolls-Royce "Nene" centrifugal-type turbojet developing a static thrust of 5,000 lbs. (2,270 kg), fitted with an afterburner for transient thrust augmentation. The Supermarine 535 does not essentially differ from its 510 precursor. Nonetheless, the 510's tail-wheel landing gear has been replaced by tricycle undercarriage in the case of the 535, necessitating slight modification in the design of the wing-root and fuselage nose.

The transition from the P. 1052 to the new Hawker P. 1081 was probably not quite as simple. Here, the straight tail-unit had to be replaced by a swept-back type. In addition, the jet exhaust outlet has been altered : Instead of the two jetpipes mounted in the fuselage behind the wing leading-edge of the P. 1052, the P. 1081 shows a single jetpipe in the tail, apparently in order to simplify the installation of the afterburner.

In the flight demonstrations, both types—Supermarine as well as Hawker—showed excellent manoeuvrability, and the speeds attained in power-dive probably approached the sonic range. Even though no performance figures have been released, it can safely be stated that both fighters are the fastest aircraft exhibited this year in Farnborough.

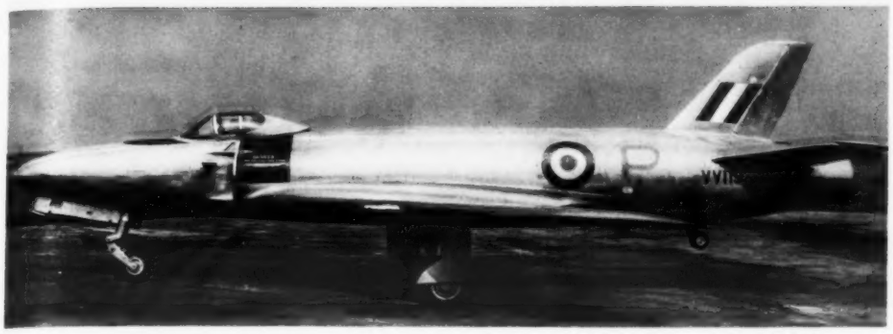
So far the Supermarine 535 is regarded as a purely experimental fighter type ; nothing is known as yet concerning production. In contradistinction to this, the Hawker P.1081 is said to have been planned for large-scale production by the Australian Commonwealth Aircraft Co. in Melbourne.

Armament ? Here, too, exact data are not yet fully obtainable : The Supermarine 535 was fitted out with four 20-mm wing-cannon, whereby the wing arrangement once again probably proved deceptive and will be replaced by installation in the fuselage nose ; the P. 1081 will in all probability likewise be armed with four 20-mm cannon or 30-mm cannon for heavier fire. The latter type is also to carry a considerable load of rocket projectiles and shrapnel bombs for ground-target assault.

Further Development of Existing Fighter types

A number of different developments of the standard British fighters —De Havilland "Vampire" and Gloster "Meteor"—were exhibited at this year's display. These constitute additional evidence of the quality of the basic types.

In the preceding year, data concerning the *D.H. 112 "Venom" single-seater fighter* and the *D.H. 113 two-seater night-fighter* were already partially released. Both aircraft are further versions of the "Vampire," whereby the D.H. 112, with its "Ghost" turbojet developing a 5,000-lb. (2,270-kg) thrust, naturally shows considerably better performance than its "Vampire" predecessor (powered with a "Goblin" turbojet developing a 3,000-lb. = 1400-kg thrust). The D.H. 112 "Venom" has now been in production for some time and will probably very soon be supplied for service operation. The D.H. 113 two-seater night-fighter is fitted with a new production series of the "Goblin" centrifugal-type turbojet whose thrust performance has so far not been revealed. The "Venom" differs from the "Vampire" by its slightly swept-back wing of smaller profile thickness and larger area, whose



The Vickers-Supermarine 535 attains a speed of more than 600 m.p.h. (1000 km p.h.) in horizontal flight.

low wingloading promises good flight performance in high-altitude combat. A comparison of the D.H. 113 with the "Vampire" shows hardly any modification of the wing but considerable alteration in the fuselage : The two-seater cabin and the radar equipment housed in the nose have necessitated the construction of a 4-ft. (1.2-m) longer fuselage nose of increased diameter.

The RAF has apparently elaborated a new program for night-fighters, since otherwise it would be scarcely possible to explain De Havilland's reasons for presenting, in addition to the only recently developed D.H. 113, the even newer "*Venom N.F. 2*" *two-seater night-fighter* at Farnborough. At any rate, this type is probably superior to the D.H. 113, if only by virtue of its bigger powerplant (D.H. "Ghost") and better aerodynamic design.

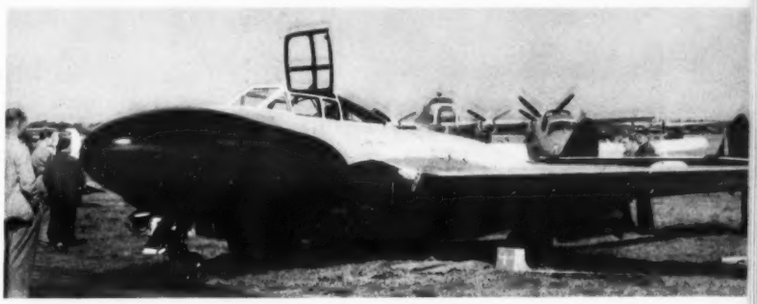
A few words concerning the other standard RAF fighter, the twin-jet Gloster "Meteor." Since 1949, the "Meteor 8" version (with Rolls-Royce "Derwent" turbojets) has been in large-scale production. This year, the "*Meteor N.F. 11*" *two-seater night-fighter* (likewise powered with Rolls-Royce "Derwent" turbojets) attracted particular attention, whereby this type also speaks for the importance of the RAF's night-fighter program. The Armstrong Whitworth works belonging to the *Hawker Siddeley Group* and already accupied with the production under licence of the "Meteor 8" of its affiliate in Gloucestershire, developed the N.F. 11 from the "Meteor 7" and "Meteor 8" and has now been awarded a contract for production. This night-fighter is looked upon as the fastest British aeroplane of this category and as a candidate for the night-fighter formations of those countries adhering to the Atlantic Pact.

No visitor to Farnborough could overlook the fact that 20-mm. cannon still are the standard armament of British aircraft. It is true, the British can point out the fact that some of the most recent US fighters also often carry only 0.5-in. (12.7-mm) machine-guns ; nevertheless, this constitutes no justification for such measures. Beyond all doubt, the higher flying speeds and more powerful defense armament of modern bombers, as well as the more resistant armour of modern tanks—in short, modern warfare—necessitate a reform of aircraft armament.

In this connection, the "*Ground Attack Meteor*" developed specially for ground-target assault from the Gloster "Meteor 8," seems to point out new perspectives : It is equipped for the installation of the most varied kinds of additional weapons. Apart from the conventional four 20-mm cannon, 16 rocket projectiles of 95 lbs. (43 kg) or four bombs of 1,000 lbs. (455 kg) can be taken on board. For long-range operation, instead of this additional armament the type can carry five jettisonable fuel tanks of more than 580 Imp. gals. (2600 lit). Finally, the installation of two further 20-mm or 30-mm cannon with copious ammunition is planned in a blister below the fuselage. Take-off with additional loading (up to 2 tonnes) will be facilitated by take-off rockets.

Experimental types

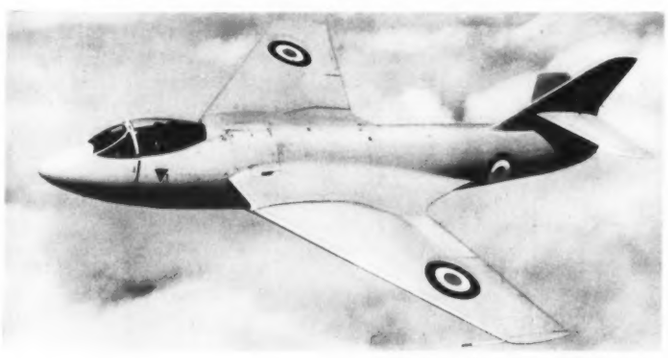
The Gloster "Avon-Meteor," "Sapphire-Meteor" and the "Avro 707B," three purely experimental aircraft, were dealt with propagandistically during the Farnborough exhibition by the daily press in articles and photos. In reality, there is no doubt that for the British industry the problems concerned are much more serious than mere propaganda.

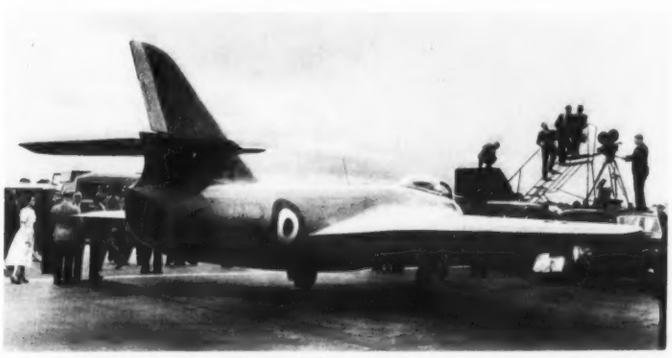


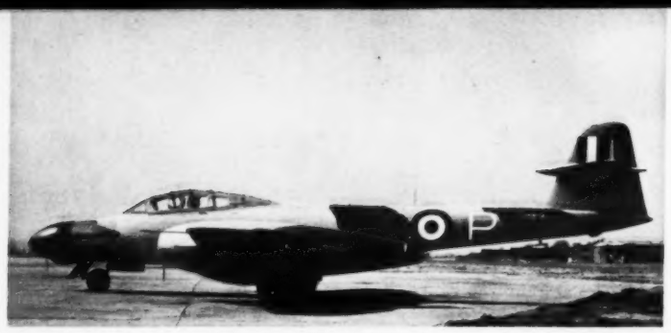
The De Havilland "Venom N.F. 2" is a two-seater night-fighter version of the D.H. 112 "Venom" single-seater. The N.F. 2—of which so far only a prototype has been built—began flight trials in August of this year.

The "*Avon-Meteor*" and "*Sapphire-Meteor*" are to be regarded as flying test-benches for engines and as the property of the corresponding engine concerns—Rolls-Royce for the "Avon" powerplant and Armstrong Siddeley for the "Sapphire." The third experimental type, the "*Avro 707 B*," possesses a delta wing with which A.V. Roe & Co. apparently hope to gather experience for a jet-propelled bomber. Whereas, however, the "Sapphire-Meteor" took a leading place in the lime-light and by virtue of its two turbojets developing a total of 14,400 lbs. (6,530 kg) thrust was described as the world's most powerful fighter—a contention of relative value if one disregards its climbing performance—, the "Avro 707 B" was veiled in complete secrecy.

Hawker P.1081 swept-back single-seater fighter. Maximum speed is likewise said to be over 600 m.p.h. (1000 km p.h.).

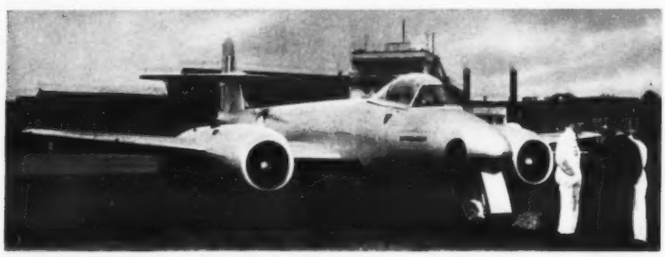






Like all night-fighters, the "Meteor N.F. 11" is a two-seater. It is in quantity production and is described as the fastest British night-fighter.

For long-range operation, the Gloster "Meteor 8" carries additional fuel tanks below fuselage and wing. Our photo shows a "Meteor 8" with extra loads: one fuel tank below the fuselage, two shrapnel bombs below the wing outer sections.



"Sapphire-Meteor," a flying engine test-bench.

Turbine-Powered and Carrier Fighter Anti-submarine Aircraft

Following the example of the USA, Great Britain is likewise taking steps for the re-armament of her carriers with the introduction of turbo-powered fighters. It is known that the flight decks of a number of ships have been reconstructed for the operation of jet fighters, and at the moment of going to print, an initial series of Supermarine "*Attacker*" jet fighters will probably have been delivered to the Naval air arm. Apart from the "Attacker," the "*Sea Hawk*," developed by Hawker Aircraft Ltd. is to be produced in large numbers for the Navy. Both aircraft are powered with the Rolls-Royce "Nene" developing a thrust of 5,000 lbs. (2270 kg) and were no new item for the Farnborough visitor.

For the sake of completeness, mention can be made of the third modern carrier fighter, the "*Wyvern T.F. 2*" of Westland Aircraft Ltd. Powered with an Armstrong-Siddeley "Python" propeller-turbine developing an equivalent shaft performance of 4,110 h.p., the type was displayed, again not for the first time, at Farnborough.

During the last war, Great Britain gained considerable experience in aircraft antisubmarine defence, though relatively late and at the cost of severe losses. In the case of a future conflict, she wishes to avoid her former sins of omission, especially as her potential opponent would nowadays possess the very latest innovations developed by the former German submarine fleet.—For defence against this menace to shipping, three new types—all powered with propeller-turbines—have been simultaneously developed and were exhibited at Farnborough for the first time: the *Fairey 17*, the *Blackburn & General Aircraft Y.B. 1* and the *Short S.B. 3*.

The Fairey Aviation Co. Ltd., who have been supplying the Navy for a great many years, have powered their Fairey 17 with an A.S. "Double Mamba" twin propeller-turbine with an equivalent shaft performance of 2,950 h.p. This three-seater—a midwing monoplane with doubly folding wing, retractable nose-wheel undercarriage and a mechanically extendable radar blister—is to replace the old Fairey "Firefly" as an antisubmarine fighter.

Blackburn & General Aircraft, who likewise have always had close connections with the Navy, have developed their Y.B. 1, which shows unmistakeable similarities with the Fairey 17, in line with the same programme. Like the latter, it is also equipped for operation from carriers and is powered with the same unit ("Double Mamba").

On the other hand, Short Bros. & Harland Ltd., for many years specialists in the construction of flying-boats, have obviously sought other paths in the execution of the antisubmarine defence programme: In their S.B. 3 they have dispensed with the twin propeller-turbine, preferring two single "Mamba" turbines, slung beneath the wing. In basic design, the type is a further development of the Short "Sturgeon" twin-engined Navy reconnaissance aeroplane. It should be stated, however, that in order to make room for radar equipment and an extra crew member for its operation, housed in the fuselage nose, the clean aerodynamic lines of the precursor type have had to be sacrificed. Despite the clumsy appearance of the fuselage nose, the S.B. 3's performance at Farnborough was very convincing.

A.V. Roe & Co. is carrying out airflow tests on a delta wing with the 707 B. It is presumed that the experience so gained with the 707 B will supply the basic data for the design of a jet-propelled bomber.

The Hawker "Sea Hawk" is intended for carrier operation. It is fitted with upfolding outer wing panels and a deck landing hook. Pilot cabin is pressurized and equipped with ejector seat.

. . . and new bomber developments?

Were any new bombers shown at Farnborough?

The average visitor will immediately point to the twin-jet bomber of the English Electric Co. Ltd. which—considerably improved after its initial appearance last year—was presented in the form of the "*Canberra B. 2.*" The type's excellent flight characteristics made a very favourable impression, as did its predecessor. It can be assumed that the "Canberra" is already known to the readers of these pages*. It has now become the "pièce de résistance" amongst Britain's bomber developments. In addition, it is the logical successor to the De Havilland "Mosquito" (piston engines), operated so successfully in the last war as a light bomber, night-fighter and long-distance reconnaissance aircraft: At the time all armament was dispensed with in favour of greater bomb load and fuel reserves, reliance being placed on its high speed for defence. The "Canberra" likewise carries no defence armament; its crew of three would be completely without defence in the case of aerial combat. This is a point of view which remains debateable, in view of today's high-altitude fighters and ground target defence fighters.

Amongst the experimental aircraft, mention has been made of the single-engined "Avro 707 B," with the opinion that the type repre-

* Cf. "The English Electric Canberra" in INTERAVIA, Review of World Aviation, No. 1-2, 1950, pp. 71-74.

Bombs, torpedoes and rocket projectiles make up the armament load of the Westland "Wyvern T.F. 2" carrier-fighter.

sented the first development stage of a later jet bomber. How long these trials will last, or their ultimate aim, are matters purely for speculation. The transition from the single-engined to multi-engined design already involves considerable problems.—But it is widely reported that Handley Page, the traditional bomber specialist, is engaged in the design and perhaps even the development of a four—or six-jet bomber.

The *bomber development* originating from the *D.H. "Comet"* four-jet commercial transport aeroplane could be judged somewhat more realistically. The British Ministry of Supply has ordered two aircraft of this type for test purposes, and intends to fit them with the big Rolls-Royce "Avon" centrifugal-type turbojets (thrust : 6,000 lbs. = 2,720 kg). Is this to form the basis for a new British long-range bomber ?

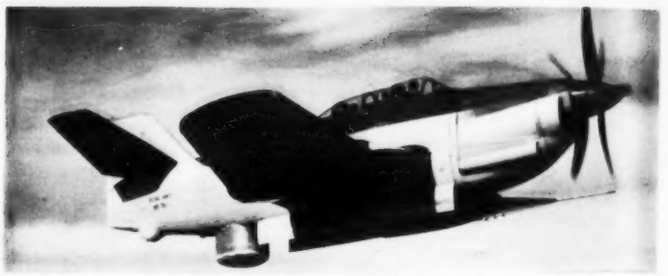
In point of fact, even to-day the Royal Air Force would not be forced to rely on long-range bombers of British design, now that the USA has delivered considerable numbers of the Boeing B-29 "Superfortress," has stationed several squadrons of Boeing B-50s in Great Britain, and if necessary could be on the spot very quickly with B-36s. At any rate it can be doubted that Britain intends to go back to museum pieces like the Avro "Lincoln" or "Lancaster." With the strategic formations of her US ally, Great Britain possesses a bomber force of tremendous impact and, as a logical consequence, could concentrate her aircraft industry on the production of night-, carrier- and antisubmarine fighters.

Transport and training aircraft

Only one military transport aircraft was shown at Farnborough : the four-engined Blackburn & General Aircraft *GAL-60* powered with Bristol "Hercules 261" engines each developing 2,000 h.p. A

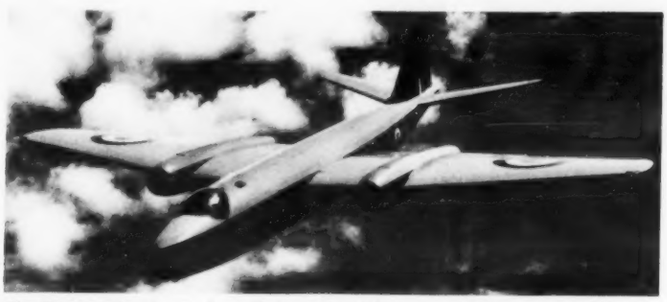
Type	Power plant	Span	Length	Wing-Area
Vickers-Supermarine 535	1×R.-R. "Nene" 5000 lbs. (2270 kg) thrust afterburner	31 ft. 8 ½ in. 9.67 m	42 ft. 11 in. 13.08 m	295 sq.ft. 27.4 m²
Hawker P. 1081	1×R.-R. "Nene" 5000 lbs. (2270 kg) thrust afterburner	31 ft. 6 in. 9.60 m	37 ft. 4 in. 11.38 m	258 sq.ft. 24.0 m²
De Havilland "Venom N.F. 2"	1×D.H. "Ghost" 5000 lbs. (2270 kg) thrust	41 ft. 9 in. 12.72 m	34 ft. 7 in. 10.54 m	279 sq.ft. 25.9 m²
Armstrong Whitworth "Meteor N.F. 11"	2×R.-R. "Derwent 8"	43 ft. 0 in. 13.11 m	48 ft. 6 in. 14.78 m	374 sq.ft. 34.7 m²
Gloster "Meteor 8"	2×R.-R. "Derwent 5" 2×3600 lbs. (1630 kg) thrust	37 ft. 2 in. 11.33 m	44 ft. 7 in. 13.59 m	350 sq.ft. 32.5 m²
Rolls-Royce "Avon-Meteor"	2×R.-R. "Avon" 2×6000 lbs. (2720 kg) thrust	37 ft. 2 in. 11.33 m	43 ft. 6 in. 13.26 m	350 sq.ft. 32.5 m²
Armstrong Siddeley "Sapphire-Meteor"	2×A.S. "Sapphire" 2×7200 lbs. (3265 kg) thrust	37 ft. 2 in. 11.33 m	43 ft. 6 in. 13.26 m	350 sq.ft. 32.5 m²
Avro 707B	1×R.-R. "Derwent" 3500 lbs. (1590 kg) thrust	33 ft. 0 in. 10.06 m	30 ft. 6 in. 9.30 m	—
Vickers-Supermarine "Attacker"	1×R.-R. "Nene 3" 5000 lbs. (2270 kg) thrust	36 ft. 11 in. 11.25 m	37 ft. 6 in. 11.43 m	226 sq.ft. 21.0 m²
Hawker "Sea Hawk"	1×R.-R. "Nene 4" 5000 lbs. (2270 kg) thrust	36 ft. 6 in. 11.13 m	38 ft. 4 in. 11.68 m	268 sq.ft. 24.9 m²
Westland "Wyvern T.F. 2"	1×A.S. "Python" 4110 equiv. shaft H.P.	44 ft. 0 in. 13.41 m	42 ft. 3 in. 12.88 m	356 sq.ft. 33.1 m²
Fairey 17	1×A.S. "Double Mamba" 2950 equiv. shaft H.P.	54 ft. 4 in. 16.56 m	43 ft. 0 in. 13.11 m	—
Blackburn & General Aircraft Y.B. 1	1×A.S. "Double Mamba" 2950 equiv. shaft H.P.	44 ft. 1 ⅜ in. 13.45 m	42 ft. 5 in. 12.93 m	—
Short S.B. 3	2×A.S. "Mamba" 1475 equiv. shaft H.P.	59 ft. 9 in. 18.21 m	—	—
English Electric "Canberra B. 2"	2×R.-R. "Avon" 2×6000 lbs. (2720 kg) thrust	64 ft. 0 in. 19.51 m	65 ft. 9 in. 20.04 m	960 sq.ft. 89.2 m²
Blackburn & General Aircraft GAL-60	4×Bristol "Hercules 261" 4×2000 H.P.	162 ft. 0 in. 49.38 m	99 ft. 2 in. 30.23 m	2916 sq.ft. 271.9 m²
De Havilland D.H. 115 "Vampire-Trainer"	1×D.H. "Goblin"	—	—	—
Handley Page (Reading) H.P.R. 2	1×A.S. "Cheetah 18" 420 H.P.	37 ft. 0 in. 11.28 m	29 ft. 11 in. 9.12 m	223 sq.ft. 20.7 m²
Percival P. 56	1×A.S. "Cheetah 18" 420 H.P.	35 ft. 2 in. 10.72 m	28 ft. 6 in. 8.69 m	214 sq.ft. 19.9 m²

A particular characteristic of the Fairey 17 anti-submarine fighter is the doubly folding wing. The type is powered with an A.S. "Double Mamba" twin propeller-turbine. On the fuselage underside can be seen the cover of the bomb bay and the radar blister (retracted).



Blackburn & General Aircraft Y.A. 5 (R.-R. "Griffon" piston engine) with extended radar blister and opened bomb bay. The Y.B.1 derived from the Y.A. 5 differs in its A.S. "Double Mamba" propeller-turbine.

The Short S.B. 3 is likewise planned for anti-submarine defence.



The English Electric "Canberra B. 2" equipped for a crew of three has a pressurized cabin and is installed for jettisonable reserve fuel tanks on the wingtips.

Blackburn & General Aircraft's GAL-60 troop and cargo transport aircraft. The useful space is divided into upper and lower decks by a floor.

De Havilland D.H. 115 "Vampire-Trainer" with two side-by-side seats and complete dual controls.

Percival P. 56 for basic training.

high-wing monoplane with fixed nose-wheel landing gear, the type has obviously been designed for purely utilitarian purposes at the cost of aerodynamical finesse. Its payload amounts to 15 tonnes ; to facilitate loading and unloading, a ramp has been built into the rear fuselage. Here too, it can be pointed out that the British industry does not have to partition because of transport construction, since Douglas, Lockheed and above all Fairchild are already specialized in the domain, are tooled for quantity production and ready for short-term delivery.

Amongst training aircraft, it is understandable that the De Havilland *D.H. 115* "*Vampire-Trainer*" for the training of jet fighter pilots, about whose existence nothing was known up to the opening of the SBAC Display, met with particular interest. With this type, the Hatfield company are now following the path pioneered by Lockheed (TF-80) and Gloster ("Meteor 7") with the development of two-seater trainers parallel to the operational service type, for jet pilot instruction. The D.H. 115 is a development of the D.H. 113 two-seater night-fighter, but corresponds also to the basic D.H. 100 in equipment and instrumentation. In view of the widespread popularity of the "Vampire" (Atlantic Pact countries, as well as Sweden and Switzerland), the new trainer will probably meet with considerable demand.

Handley Page (Reading) and Percival Aircraft Ltd. presented their new *H.P.R. 2* and *P. 56* two-seater basic trainers. Both types were developed in line with the same RAF directives and show the same constructional design : low-wing monoplane with fixed tail-wheel landing gear, side-by-side seats, Armstrong Siddeley "Cheetah 18" 420-h.p. engine.

So what was to be seen at the 1950 Farnborough Display ?

If one disregards those commercial transport aircraft already known and undoubtedly improved, to some extent on order and even shortly to be delivered—such as the D.H. "Comet," Airspeed "Ambassador," Vickers "Viscount" and Bristol "Brabazon"—then Farnborough was a "presentation of arms in the West."

This presentation of arms revealed that the British aircraft industry is in a position to supply the RAF as well as the countries adhering to the North Atlantic Pact with first-class equipment in the domain of fighters in the orthodox, night, carrier and antisubmarine defence categories. Also quantitatively—by virtue of production licences—it will gradually be able to meet all requirements.

The advance held by Great Britain in the field of turbojet power plant is still apparent. Nonetheless, the "three-year" estimation of this advance made by many over-enthusiastic experts in 1950 can be regarded as somewhat irresponsible. In the armament race, three years are a long period. To-day, turbine engines are being built and developed all over the world, and not to the least extent in the USA, the Soviet Union and its satellites behind the Iron Curtain. It is doubtful that American jet engine design is lagging behind British construction by three years at the present time. And Russian production ? Qualitatively, it is probably far behind the British. Quantitatively ?... It is here that the guesswork begins.

*

Any report on the "presentation of arms in the West" at Farnborough would be lacking if, apart from the factor of flying equipment, the *human factor* were not emphasized. Weather conditions were catastrophic : rain, wind, poor visibility—perfect flying weather ! The demonstration before highly-critical visiting experts of new and in some cases untested prototypes in aerobatic flight, under these conditions, was truly a performance. It testifies eloquently to the quality of British test pilots and of British training.

Economic Aspects of the British Aircraft Industry

With a Pince of Salt . . .

Graduate students seeking a theme for a doctoral dissertation in national economy are ill advised to undertake an economic analysis of the British aircraft industry. Three obstacles will impede their research and discourage further efforts : The formation of trusts within the industry, the scantiness of its publicity and—a distortion of the picture which, however unique and conditioned by the times, is nevertheless difficult to allow for : the devaluation of the pound in 1949.

Trust formation ? A single instance may suffice : The *Armstrong-Siddeley Development Company Limited,* a concern affiliated with the Hawker-Siddeley group, controls the following companies : A. V. Roe & Co. Ltd., A. V. Roe (Canada) Ltd., A. W. Hawksley Ltd., Air Service Training Ltd., Armstrong Siddeley Motors Ltd., Gloster Aircraft Co. Ltd., Hawker Aircraft Ltd., High Duty Alloys Ltd., Hawker Sanders Ltd., Hawker Siddeley Transport Ltd., Norstel Scaffolding & Hire Ltd., Northern Steel Scaffolding & Engineering Co. Ltd., Sir W. G. Armstrong Whitworth Aircraft Ltd., Templewood Engineering Co. Ltd., Aluminium Wire & Cable Co. Ltd.

If the financial nature of the connections between this purely aeronautical concern and companies foreign to aviation is difficult to untangle, then clear delimitation between an armament concern such as Vickers with its two aircraft factories and its impressive number of munitions factories, ship-building companies, locomotive and chassis factories is a pure impossibility. In so gigantic an array of the most varied fields of activity, who would dare to claim his ability to discern where aeronautical interests begin and where they end ?

And the paucity of public information ? If statistical reports and financial balance sheets normally serve—as is so often averred—for the concealment of facts, this is, of course, especially applicable at a time when, in the interest of national defense, both Government authorities and industrialists take every measure possible to prevent their cards from being exposed, or even worse, instead of revealing an ace of spades show an innocent nine of diamonds.

Our English correspondent accompanied the official documentation for this article with the following statement :

> "It is only appropriate to mention that all published figures can claim accuracy in a very generalized sense only, since security requirements exclude the release of more important information from the beginning. Not only the Government authorities, but the majority of companies are more than reticent. In any case, the reader is at liberty, after having been duly warned, to draw his own conclusions from the graphs and tables. And on the other hand, we feel that English figures are not less reliable than those released by other countries." (sic !)

The Meager Years

It is only a few weeks ago—to be precise, since the public announcement of the British armament programme released on July 26, 1950—that the English aircraft industry began to overcome the crisis precipitated in the beginning of 1950 by the cancellation of orders on the part of RAF Transport Command. This last post-war crisis was by no means the only one. The British aeronautical industry was, of course, no less spared from the setbacks of the post-war years than its great competitor on the other side of the Atlantic. British aircraft industry shares were not only affected —together with the entire industry of Great Britain—by the fuel crisis of the winter of 1946-47 and the blocking of the pound in the summer of 1947, it also felt the repercussions of the period of dearth which began in 1946 with the withdrawal of Government orders. Even more disturbing than these particular influences was the uncertainty resulting from the vacillations of the Government construction programme during the last five years.

*

Although it entered the post-war era with the second largest production capacity after the USA, the British aircraft industry nevertheless suffered from a singularly one-sided orientation. With a view to concentrating the war effort in general, the Allies had agreed that the entire development of transport and observation aircraft (both aeroplanes and helicopters) be concentrated in the American industry, which disposed over sufficient manpower to accomplish this task without neglecting military offensive types as such. This decision—essential as it was to the final victory of the Western powers—had nevertheless an incisive and long-standing effect on the *civil construction programme* of England. With the exception of a number of small design team nuclei engaged upon the projects of the Brabazon Committee, the entire technical resources of the British aeronautical industry were concentrated upon the production of fighters and light and medium bombers at the end of the war. To this must be added the fact that the aims of Lord Brabazon's planning committee were exceedingly comprehensive. They included types so varied as the de Havilland "Dove," Bristol "Brabazon," Handley Page (Miles) "Marathon," Vickers-Armstrongs "Viscount" and the de Havilland "Comet," etc.

It can naturally be argued as to whether or not British lack of experience in the construction of modern transport aircraft was an unconditional disadvantage. Undoubtedly, it led to designs with a considerable number of teething troubles, whose persistence in some cases for years could rather be more truly likened to the difficulties of adolescent adjustment. On the other hand, the lack of any basic scheme facilitated the decisive break with tradition, so that certain new types show evidence of much greater vision than contemporary American developments. The de Havilland "Comet," Vickers-Armstrongs "Viscount" or Airspeed "Ambassador" can be cited as examples.

Unfortunately, this far-sightedness in design has been to a large extent offset by a paralysing indecision on the part of the Government (a responsibility shared by the Ministries of Civil Aviation and of Supply, as well as the British Overseas Airways and British European Airways Corporations), so that the initial impetus manifested in prototype development has been lost without a trace, owing to delays in starting production.

*

With regard to *military flying equipment,* the picture is a shade brighter. In this domain, Government policy has been to concentrate consistently on the production of two jet fighters, the Gloster "Meteor" and de Havilland "Vampire," whilst all other projects were supported only as far as prototype construction. As compared with planning for civil purposes, this was a completely realistic policy. It took into account Britain's chronic shortage of manpower, quite inadequate for the development of vast numbers of prototypes such as possible in the USA. From the military point of view the Government was influenced by the consideration that the RAF could and would have to be satisfied with these two standard jet fighter types — now in use throughout the majority of air forces of the Western Union — until research had further clarified the aerodynamic problems involved in sonic-range flight. This condition has to a certain extent now been fulfilled, so that the RAF can shortly be equipped with new fighters in the form of the de Havilland "Venom," while the Naval air arm is scheduled to have Vickers-Armstrongs "Attackers" this year, to be followed shortly afterwards by the Hawker "Seahawk."

In the field of heavy military types, initially a path of considerable promise was taken,

inasmuch as the Avro "Lincoln" was developed to a jet-propelled bomber with no other intermediate stage. However, this programme was initiated with a tortuous slowness, and the only visible result so far is the twin-jet "Canberra," the first product of a firm hitherto not engaged in the construction of modern aircraft, namely the English Electric Company.

*

The construction of *small aircraft* is today practically at a standstill, if one disregards the small number of trainers developed for the RAF and a single new private aircraft, the "Chrislea." Undoubtedly, light airplanes are only a paying proposition when their producers are able to benefit by Government support in some form or other—such as by "assured" orders as in the case of the winners of French design competitions. On the other hand, the development of helicopters has been remarkably good, a fact to be attributed rather to private initiative than to Government help. Certain types have enjoyed a considerable popularity, though this has been sadly marred latterly by a disproportionately large number of accidents, due, it is true, rather to bad luck than to bad design.

*

The considerable success obtained in the design of *aero-engines* is primarily attributable to the firm policy of the Controller of Research and Development (Air) at the Ministry of Supply, Sir Alec Coryton, who has been able to assure Great Britain a lead of several years in the development of jet-propulsion engines and airscrew turbines. On the other hand, the piston engine has been to some extent neglected ; no new types have appeared since the end of the war.

For the sake of completeness, it can be mentioned that British *accessory design and manufacture* has been maintained at a healthy pitch so that it is perfectly capable of rapid response to any sudden increase in Government orders. The two airscrew companies, Rotol and de Havilland, have created a number of convincing designs for the solution of the peculiar problem of the airscrew turbine, and each has succeeded in producing reliable contra-rotating reversible-pitch types. Even the wireless and instrument manufacturers, who in peacetime find it virtually impossible to cover development costs from aircraft orders, have gone ahead with the design of up-to-date apparatus, in all probability stimulated by its prestige value.

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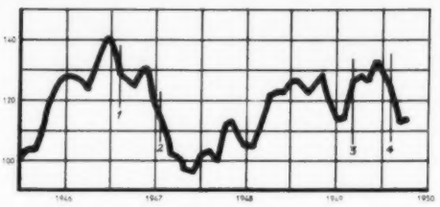
Though this survey has in no way dramatized the post-war difficulties, it nevertheless shows that the five meager years have not gone by without affecting the British aeronautical industry.



Stock Market Trends of the British Aircraft Industry (10 leading concerns) for 1946 to 1950

January 1946 = 100.
1. Fuel Crisis. 3. Devaluation.
2. Convertibility Crisis. 4. Transport Command Cuts.

Here is the market development of ten leading aircraft shares from 1946 to the beginning of 1950 :

From Export Demand to Export Ban

In the crisis of the post-war years, the question of export played an incomparably greater rôle for the British aeronautical industry than for that of the USA, which could rely, despite severe reductions in contracts, on a much greater domestic market. "Export or die" were the alternatives confronting the British manufacturers. In consequence, the tendency existed to export everything that was not tied down or nailed down, from long-existing stocks up to the most modern jet-propulsion power plant. Particularly illustrative of this is the fact that in the year 1949 the entire British aircraft production went abroad :

Production and Export in the British Aircraft Industry *

1949	*Number of Aircraft produced*	*Number of Aircraft exported*
January	42	34
February	39	34
March	42	35
April	28	18
May	69	68
June	47	46
July	39	39
August	31	30
September	30	30
October	30	30
November	22	22
December	32	32
Total	451	418
1950		
January	33	30
February	50	44

According to statistics by the Society of British Aircraft Constructors, the export of aircraft aero-engines and accessories more than doubled during the years from 1946 to 1949. On the other hand, also the importation of transport aircraft underwent considerable increase due, to no mean extent, to British tardiness in the development of big commercial transport types.

*) This compilation comprises only civil aircraft and those military types sold directly by their manufacturers. Delivery from government to government is disregarded.

British Export and Import of Aircraft, Aero-Engines and Accessories

	Exports in £	*Imports in £*
1946	14.563.419	1.145.306
1947	25.055.200	3.762.549
1948	26.004.784	7.102.207
1949	34.215.177	17.362.413
January 1950	2.721.544	1.183.803
February 1950	2.787.119	1.512.638
March 1950	3.429.985	2.188.388
April 1950	3.319.187	1.380.934
July 1950	3.733.667	

Satisfactory as this was for the participating concerns and for Great Britain's trade balance —this all-out sale gradually began to exceed the limits permissible from the point of view of those responsible for national defense. In the middle of July, 1950, the delivery to Egypt, Argentina and the USSR of the newest British jet power plant was the object of critical comment in the House of Commons. Two months later, the Ministry of Defence decided to place a ban on armament export to all countries not adhering to the Atlantic Pact. And even though this export limitation applies only to the newest aircraft and aero-engine types, it will nevertheless impede the execution as well as the attainment of many a profitable contract.

Nor was the sky less cloudy or prospects brighter for the domestic military market. Driven to economies in the defense budget, in the beginning of 1950 the Cabinet demanded that the Air Ministry also agree to cuts in its budget. Reductions in the program for the production of bombers were unthinkable, equipment renewal of the fighter formations was in full swing, delay in the delivery of trainer aircraft could not be considered. As a result, it was the RAF Transport Command which had to bear the brunt. Chief sufferers were Handley Page with contracts for "Hastings," Vickers-Armstrongs with "Valetta" and Bristol as the power plant manufacturers for both types.

Requests for reconsideration on the part of the factories affected and the Society of British Aircraft Constructors—which feared massive staff reductions—were initially unsuccessful . . . until on July 26, 1950, the turning point arrived. The USA demanded a substantial armament contribution on the part of all industrial member states of the Atlantic Pact. For reasons of prestige alone, Great Britain could not afford to stand aloof, and estimated the necessary expenditure at £3,000,000,000, to be used for her rearmament during the next three years. On September 13, 1950, Prime Minister Attlee announced to the House of Commons that Britain's fighter strength was to be increased and that new RAF units were to be provided

for the occupying forces on the European Continent. Mention was also made of quicker delivery of bombers (English Electric "Canberra") and of other types. Increase of the personnel of the munitions industry was likewise taken into consideration, and the Government stated in the House of Lords that the war-time aircraft shadow factories were ready to begin activities anew at any moment.

In other words . . . excellent business prospects throughout.

Notwithstanding, British aeronautical circles continue to express a certain skepticism regarding the economic consequences of this programme. In the middle of September, a report from London states that so far . . . "despite all the hullaballoo and the £3,000,000,000, not the slightest sign of a new contract for the aircraft industry can be discerned on the horizon. Nor have the former contract cancellations been rescinded."

Nevertheless, in view of the present state of world affairs, there is probably no real reason for nervousness on the part of the British aeronautical industry. It can quietly await its opportunity, placing its confidence in the temperament of Churchill, who will in all likelihood not allow the discussions concerning the allocation of the £3,000,000,000 to come to a standstill.

How's business? . . .

Prior to official announcement of the details of the new armament programme, it would be useless to ask a British aeronautical industrialist, with a confidential wink : "I asy, old boy, how are things from the business point of view ?"—Meanwhile, far be it from us to pretend that certain producers have not already very satisfactory contracts in their briefcases.

Indubitably first and foremost in this regard are two concerns whose business—as a result of skillful economic foresight and progressive ideas—remained excellent even throughout the most difficult years : *Rolls-Royce Ltd.* and *De Havilland Aircraft Co. Ltd.*

Even during the war, both companies adapted themselves, not only in theory but likewise in practice, to the development of jet-propulsion engines. Both took the point of view that, after the cessation of hostilities, nothing more could be undertaken with long-standing reserve stocks and obsolescent types, such as formerly could be sold to Mr. Somebody-or-Other (to be geographically more precise, Señor Somebody-or-Other). As a result, Rolls-Royce developed the "Derwent" and "Nene" jet engines, while De Havilland for its part constructed the "Goblin" and "Ghost" gas turbine power plant, with which its "Vampire" and "Venom" fighters are powered.

It is perhaps not necessary to state that even the older horses in the stables of both firms are still well able to earn their oats. With the internationally renowned piston engines "Merlin" and "Griffon," Rolls-Royce will probably be able to do business for years to come, while De Havilland, despite its new jet types, has not yet written off its in-line engine "Gipsy" or its fighter aeroplanes "Hornet" and "Sea Hornet."—(Remarkably enough . . .)

With regard to the various subsidiaries of the third large concern, *The Hawker Siddeley Group Ltd.*, very differing results are to be noted. Contrary to factories with marvellous results such as Gloster Aircraft Co. Ltd. ("Meteor") or A. V. Roe (Canada) Ltd., the English firm A. V. Roe & Co. Ltd. has probably earned neither laurels nor crisp bank notes with its "Tudor" series. However, as previously stated, the activities of this concern comprise so many varied fields of interests —to mention only the High Duty Alloys Ltd., who supply the entire British industry with aluminium alloy products—that individual profitless undertakings have no effect whatsoever on the sound financial position of the group.

Both of the aircraft works affiliated with the armament concern *Vickers Ltd.*, notably *Vickers-Armstrongs Ltd.*, Aircraft Section in Weybridge and *Supermarine Works*, have developed firmly established types, whose production results in very substantial profits. But whilst production of Supermarine's single-jet fighter "Attacker" has continued without interruption, the plans elaborated by the Weybridge factories for the production of their military transport "Valetta" (military version of the "Viking") have been to some extent set aside by the RAF Transport Command's contract annulments. It is not necessary to emphasize that the resulting loss of profit is hardly of any significance to a concern like Vickers.

The main trump of the *Bristol Aeroplane Co. Ltd.* was the production of heavy piston engines. Somewhat later, and without the same degree of success as Rolls-Royce and De Havilland, the company began the design of turbine engines. It then turned to the development of commercial transport types ; with its Bristol 170 "Wayfarer"/"Freighter" it has brought to market a passenger-cargo aeroplane which has received popular approval as a willing beast of burden. On the other hand, it is hardly likely that the "Brabazon" (a development for reasons of prestige, at Government cost) will prove in the long run to be profitable.

The *Fairey Aviation Co. Ltd.*, who have delivered hundreds of "Firefly" naval fighters to the RAF as well as to Canada, Australia,

Quotations of Some British Aviation Securities

	Authorized Capital £	*Issued Capital* £	*Ordinary Shares* £	*Nominal Value of Share*	*Dividend for 1948 in %*	*Dividend for 1949 in %*	*1948 Quotations* Highest	Lowest	*1949 Quotations* Highest	Lowest	*Quotations* 14/9/50
Alvis	750 000	700 000	600 000	5s	6	6	4/11	2/10	4/7	3/1	4/6
Associated Electr. Ind.	8 696 050	8 669 240	6 000 000	£1	15	15	87/6	69/0	80/3	68/3	76/0
Blackburn	1 250 000	916 812	916 812	10s	10	10	11/1	8/3	13/6	10/4	10/7 1/2
Bristol	3 900 000	3 900 000	3 300 000	10s	10	10	16/10	11/3	17/4	13/10	16/0
De Havilland	2 800 000	2 628 275	1 827 275	£1	10	10	40/6	32/0	43/3	32/3	42/6
English Electric	6 500 000	6 174 575	3 338 731	£1	10	10	58/9	43/6	49/6	40/9	47/3
Fairey	1 250 000	1 027 750	1 027 750	10s	20	20	25/1	15/6	25/6	19/3	23/10 1/2
Folland	498 000	300 000	300 000	6s	6	6	5/5	3/8	4/10	3/2	6/6
Handley Page	572 539	572 539	373 395	5s	22 1/2	40	30/0	18/3	31/0	24/0	27/3
Hawker Siddeley	6 000 000	3 455 578	1 905 587	5s	32 1/2	32 1/2	25/1	16/0	27/9	20/3	29/2 1/4
Rolls-Royce	2 500 000	1 150 000	1 005 000	£1	20	20	£5 1/16	86/0	£5 1/4	80/0	£5 4/6
Vickers	—	—	12 315 484	£1	12 1/2	6 1/4*	33/10	23/6	30/7	24/1	30/6
Westlands	—	—	4 000 000	5s	7 1/2	5 1/2	6/6	4/1	6/3	4/7	6/1 1/2

*) Capital doubled in 1949. (without guarantee)

Holland and Sweden, and in addition operates an extremely profitable accessory, maintenance and overhaul business, can be regarded as beyond all financial doubt, while in the case of *Handley Page Ltd.* we are concerned with a firm headed by one of the most shrewd, conservative and realistic minds in Great Britain to-day. Handley Page does not know the meaning of loss, the company steers a perfectly safe financial course. When it is unable to market profitable aircraft, its activities are limited at the very worst to the sale for years of manufacturing licences (for instance, its slotted wing).

The *English Electric Co. Ltd.* has only recently entered the market with its own designs, but shows definite prospects of gaining a place amongst the ranks of the foremost British producers.

As a smaller but very efficient undertaking, mention can be made of *Westland Aircraft Ltd.*, whose subsidiary Normalair Ltd. has already achieved an enviable reputation for pressure cabin equipment.

*

This survey in capsule form may be concluded with the observation that to-day's world political crisis finds the British aircraft industry well prepared—capable at any time of meeting emergency requirements without special difficulties.

My first Time in the Air

Baptism (from the Greek "Baptismos" — to wash) : A sacrament calling for sprinkling of, or ablution in, water, while a ritual formula is intoned...

If we are to believe the dictionary, the customary baptismal ceremony with which air travellers are wont to celebrate their first flight has definitely no connection with the real thing. The most dyed-in-the-wool prevaricator could hardly pretend that the champagne generally imbibed on this occasion is equivalent to an "ablution." Nor could one claim that the words which are uttered have any intentionally sacred character...

But in my case, things happened quite differently... Believe it or not, I really was baptised...

The case of my aerial christening was recalled to my mind by a story I heard yesterday. Let me just repeat it again for you, before going on to speak of my first flight... and its far-from-happy ending.

The particular incident I am relating occurred before the War—you know—not this one, nor the last one, but the Great War, World War I, or the First of the Last, if you prefer it. The scene is a former hatter's "boutique" in the Passage de l'Opera, which has long since vanished following the opening of the Boulevard Haussmann. Enter a customer... and the shop-keeper hurries to serve him :

— Can I help you, Sir ?

— I'm looking for a cap. But it must be an aviator's cap...

— All right, Sir, just let me show you my collection.

And the hatter fishes out one, two, three, ten, twenty caps, which the customer untiringly tries on, one after another. But each time, after a glance in the looking glass, he doffs the offending head-gear and says with a disgusted air :

— But this isn't an aviator's cap !

The unfortunate shopkeeper ransacks his drawers from top to bottom, upsets his hat-boxes, goes through his entire stock... for in those days things were different, and shopkeepers fell over backwards in an effort to serve their clients as a matter of course, for a mere three or four francs...

In a short while the whole shop had been turned topsy-turvy ; glossy top-hats, which had stood smartly in serried ranks only a few minutes before, were mixed up with bowlers and straw-boaters in the most utter confusion. But still there was no aviator's cap to be found !

— Well, I'm very sorry, Sir, but there doesn't seem to be anything...

— Wait a moment ! I've had an idea...

And the customer picks up the first cap—the very first one he had tried on—and puts it on his head, back to front. Then he looks at himself in the mirror and his face breaks out in smiles of triumph. At last, a real, an authentic aviator's cap !

The first aviator I ever saw also wore his cap back to front, and indeed to me the sight of the vizor flapping against the back of his neck was far more convincing proof of the fact that I was standing in the presence of a modern Icarus than the frail monoplane which had just touched down on the sandy beach on its flimsy, bicycle-like wheels. I was then 5 years old—the year was 1911—and had been taken to spend a holiday on the Atlantic coast. At last, I could actually admire an aeroplane—that wonder of wonders of the new century—and an aviator !

My excitement and interest at this unexpected apparition—was it a Bleriot, or perhaps an REB ? I shall never know...—was such that I quite forgot my little spade and bucket.

— Hello, little chap ! Would you like to come up with me ?

The "aviator" had seen me, and had even spoken to me... and what words ! Struck dumb with emotion, I nodded my head in a big gesture of assent. Sinewy arms hauled me up onto the seat, the aviator climbed up behind me... and already we were in the air.

Shades of Pilatre de Rozier, of Adler, of Farman and the Wright Brothers ! These worthy pioneers could hardly have felt more jubilant than I did on making their first flight...

But if I tried to describe my youthful impressions of what it was like to be airborne for the first time to you, I would be lying, for—powerful as they must surely have been—they were effaced from my memory for ever by the welcome I received when I got back to Mother Earth again.

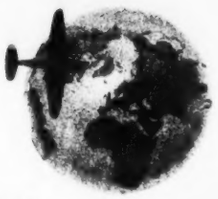
My mother was there, standing by my spade and bucket. And she lost no time in giving the newly-baptized neophyte that I was the worst spanking that he had ever received in his life.

— You little wretch, if I ever catch you doing that again...

The tears ran like rivers down my cheeks...

Ablution, ritual formula... nothing was missing from the ceremony. So I wasn't entirely wrong after all when I told you that I really did receive an aerial baptism ! And yet, even that did not succeed in killing my interest in aviation...

Georges Février.



What's in the Air? *

WHEN DANGER THREATENS, NO REMEDY IS TOO DEAR...

Aluminium, chromium, nickel, rubber, petroleum, uranium, delivery periods, manpower and again manpower... Such are the main subjects of conversation nowadays. But the question of what price should be paid for these commodities is out of place at the present juncture.

To start with *aluminium :* Faced with an ever-swelling flood of urgent orders for the domestic armament programme and for arms aid material for America's Atlantic allies, the US aluminium industry by the end of August found itself nearing bottle-neck. Official estimates set the share of the industry's production which would have to be diverted to meet the nation's defence needs at about 14 %. Those "in the know" greeted this suggestion with a cynical smile, said 30 % would be a more likely figure. Be this as it may, the US Government has embarked on several new measures to remedy the impending shortage. Since the dearth of aluminium is seemingly due less to a lack of bauxite (basic ore from which the metal is made) than to a shortage of cheap electric power for extraction of the metal by electrolysis, the Government decided to grant subsidies of $11,000,000 and $6,000,000 respectively to the US firm Reynolds Metal Co. and the Jamaican company, Jamaica Bauxites Limited, offshoot of the allpowerful Canadian company, Aluminium Limited of Canada. At the same time, the last-named firm was given a $75,000,000 order for 200,000 tons of raw aluminium to be delivered over the next three years. Finally, it was decided to step up domestic production by every available means, and to reactivate the World War II "shadow" factories which had been closed down or converted to other production.

A mere glance behind the Iron Curtain sufficed to silence any haggling about prices. In Soviet Russia production of aluminium had risen sharply from 85,000 tons in 1945 to at least 115,000 tons in 1949, and was slated to reach the 155,000-ton mark this year.

This position is generally similar as regards the other essential raw materials. On August 29th, President Truman empowered the Munitions Board to buy up supplies for the national stock-pile "at any price." At the same time the "buy American" restrictions giving preference to domestic wares were removed. At the present time, the US has a stockpile of about $2,000,000,000 worth of critical materials. The Government plans to double this reserve as soon as possible, and at the least to increase it by 7 % by mid 1951.

Changing guard at the US Defense Ministry : Left : *Louis A. Johnson*. Right : *General George C. Marshall*, American Defense Minister.

In the field of *machine tools and finished products,* demand was no less insistent. Figures published by the American Machine Tool Builders' Association have shown that in July 1950 the industry's backlog of orders was the highest since May 1943. Taking 100 as the average of production for the years between 1945 and 1947, the production index fell off to a 'low' of 48 for the month of July 1949 ; in contrast to these doldrums, the index for July 1950 was no less than 253.

Hand in hand with the increases in production and stockpiling of critical war materials went a tightening-up of *export controls*. Among other things, the export of petroleum products was made dependent on the granting of a licence for all quantities worth over $25.00. These prescriptions apply to dealings with a number of states, with the exception of Mexico.

MANPOWER, NO LESS THAN GOODS AND RAW MATERIALS, IS MUCH IN DEMAND

According to a report in the "Wall Street Journal," the scarcity of skilled personnel in the aircraft industry is becoming daily more critical, particularly on the West Coast of America, where recent dismissals of personnel—caused by the falling-off in orders during the post-war years—are beginning to make themselves felt. Employment at four leading aircraft works—Douglas, Lockheed, North American and Northrop—which between them employed no less than 225,000 workers in 1943—had dwindled off to a mere quarter of this number by the end of last year when the position was as follows :

Douglas	20,531
Lockheed	15,000
North American	18,350
Northrop	7,825
Total	61,706

Today, thoroughly-trained and experienced skilled workers and specialists are in exceedingly short supply. Although plenty of applications for jobs are being sent in, the Lockheed Company reports for instance that only about 25 % of the applicants have any specialised knowledge, and that of these only about 2 % were fully-qualified technicians. As a result of this situation, the majority of aircraft manufacturers are starting up training courses for the formation of likely applicants from all walks of life, and one firm, the Solar Aircraft Co., is even taking on female personnel.

TAKE IT EASY...

Following the slackening of business last year, which in some quarters was interpreted as heralding a widespread slump, the present spate of armaments orders undoubtedly came at an opportune moment for US industry generally. At the same time, it was evident that at the present juncture, the continuance of a liberal policy, under which the nation's economy would be free to find its own level, might bring serious dangers in its train. Hoarding of goods, as well as uncontrolled advances in prices and wages, would only aggravate still further the already perceptible tendency to inflation. As a result, Congress decided to take emergency measures to regulate the new defence economy by granting the Government carte blanche to re-establish full wartime controls as and when necessary.

In their turn, the governments of Western Europe are beginning to follow the American example. Thus

General Walter Bedell Smith, former American Ambassador to Moscow, has been appointed Chief of the American Intelligence Service.

* Based on reports published in "INTERAVIA AIR LETTER," daily international aviation news digest appearing in English and French.

Generals on tour : A military mission from Venezuela visiting the American Beech Aircraft Corp. in Wichita (Kansas). Third from right Lt.-Col. Felix R. Moreno, Chief of the Venezuelan Army and Chief of Staff Venezuelan Air Force. — Second from right : Walter H. Beech, President of Beech Aircraft. — Fourth from right : Major General Robert L. Walsh, Senior USAF Officer Inter-American Defense Board.

An Israeli military mission in Switzerland. First and second from left : Brigadier Mordehai Maklev, Deputy Chief of Staff of the Israeli Army. — Army Corps Commander Colonel de Montmollin, Chief of Staff of the Swiss Army. — Second from right : Air Commodore Ahron Remez, Chief of the Israeli Air Force.

During the last war "Lightning" fighters were made in this shed belonging to the Lockheed Aircraft Corp. of Burbank (Calif.). Nowadays, two seater allweather F-94 fighters are being assembled there.

Sweden has set up a Defence Production Board, which has asked the Swedish Parliament for full authority to purchase essential raw materials to an amount of some Kr. 300,000,000 for the national stockpile.

*

How long will the present armaments scramble go on ? The answer to such a question cannot be provided by an inquiry, however searching, in terms of defence needs and productive capacity ; rather, it must be sought in the soothsayer's crystal ball. However, it is safe to assume that today's breakneck pull will in due course slow down to a quieter tempo, provided there is some improvement in the international situation.

I-11 : Practice and sports two-seater I-11, made by the Spanish Company, Iberavia S.A. ; wooden construction, with 85 h.p. Continental engine.

A STRONG MAN MAKES WAY FOR A STRONGER . . .

Volumes have been written in the daily Press about the events surrounding the *resignation on September 12th of Louis A. Johnson from the post of US Defence Secretary, and his replacement by General George Catlett Marshall.* What is the significance of this new appointment for the outside world ? As a former member of the Board of Consolidated Vultee Aircraft Corp., Johnson in his capacity of Defence Minister was instrumental in seeing that his former firm got the lion's share of USAF contracts : his much-discussed policy of favouring the B-36 giant bomber as a strategic weapon resulted in other important aspects of defence being relegated to the background. The US Navy is not likely to forget the man who allowed its personnel to be drastically reduced, its admirals to rot in idleness and construction or its pet project, a giant 65,000-ton super aircraft-carrier, to be stopped. Faced with open opposition from Air Force circles, and looked upon with misgivings throughout US industry, the only support for Johnson's policy was to be found among certain sections of the US Army. For the outside world, however, the important question was whether Johnson really conducted his thinking on a world-wide basis, whether he had reckoned with the possibility of an outbreak of hostilities in overseas theatres (such as Korea . . .), and what his real attitude regarding Europe might be. The question has even been asked whether Democrat Johnson, who handled President Truman's electioneering funds, was not fundamentally hostile to Europe, but such a hypothesis lacks proof. Johnson's neglect of certain important defence elements, which became apparent during the Korean campaign, was the major factor in his loss of office. As far as American opinion can be judged, few tears will have been shed in the Pentagon about Johnson's departure, for the ex-Defence Secretary displayed unduly dictatorial tendencies. Johnson was wont to pride himself on being a "strong man." In the case of General Marshall, however, strength of character is tempered by wisdom and a wide range of experience. And Marshall's friendly attitude towards Europe is well-known.

That Johnson's departure should have brought other changes in its train—Under-Secretary for Defence Stephen T. Early resigned immediately afterwards—is hardly to be wondered at. Of greater interest is a new appointment, seemingly unrelated to these administrative upheavals, which has understandably received less attention in the world's news columns : we refer to President Truman's appointment of *General Walter Bedell Smith*, former US ambassador in Moscow and now Commander in Chief of the First US Army, as *Head of the US Secret Service*. In view of the destination to which most leaks of secret information from the States seem to be intended, the choice of Bedell Smith for this post is a particularly happy one. His realistic attitude towards the situation is summed up in the words : "There are no experts on Russia, only varying degrees of ignorance."

Smith's nomination also coincided with the passing of a Bill making it necessary for aircraft wishing to fly over certain "sensitive" zones of the USA (notably the uranium-bearing regions along the US-Canadian border, and the important defence production areas of the US West Coast) to obtain prior permission from the Civil Aeronautics Board, thus, in effect, setting up the wartime Defence Areas again. Under these restrictions, which apply to all domestic and foreign transport, private and military aircraft, delivery of the required authorization is made attendant on filing of flight plans with the CAB. Also there is no denying that the official attitude towards amateur and professional photographers is definitely more "finicky" than in the past.

A rare snapshot ! Four North American F-86 "Sabre" jet fighters of the 81st Fighter Squadron of the USAF shortly after take-off from Larson A.F. Base near Moses Lake, Washington.

AUTUMN MANOEUVRES "EN FAMILLE"

The three-day air exercises (Exercise "Broadside") held in the Paris—Amsterdam area by the air forces of the Western Union States (Belgium, France, Great Britain and Holland), with the co-operation of American long-range bombers, were aimed at testing the fighter cover and radar warning system protecting the west European industrial districts. Considerable weaknesses came to light. Although there was clear weather over the Paris region, the defence was not able to repulse successfully the bomber units flying in from Great Britain and Western Germany. Fighter control, radar screens and communications were not equal to their task.

Among other things, co-operation between the units of five different nationalities presumably still had certain "teething troubles" to encounter. Experience of World War II suggests such an assumption. How far-reaching the results of faulty understanding between allied air forces can be has just been shown again in Korea, where British ground troops were fired on by error by American ground-strafing aircraft.

Large-scale exercises by the British Army of the Rhine and the RAF, in which Danish, French and American troops took part, were held in West Germany from 24th to 30th September.—Immediately after the conclusion of the exercises held by the Turkish Fleet and Air Force in the Sea of Marmora (the biggest of their kind undertaken), combined exercises by all three Turkish armed forces, in which 50,000 men took part, began on the Izmid Peninsula. The object of these exercises was to push back an invader who had penetrated into the country.

AIR TRANSPORT SEEKING STAFF

The increased demand arising out of the USA-Japan-Korea air lift has led to a marked shortage of transport pilots. For each of the 150 military and transport aircraft at present in use (60 four-engined aircraft leased from 12 public transport and private charter companies) four complete crews must be provided to ensure maximum possible utilization of the available aircraft. Pan American Airways contacted 140 pilots whom they had dismissed at the beginning of 1950, but met with little response. American Airlines are shortly to take on more than 80 pilot trainees.

PAA's shortage of pilots will scarcely be helped by *the amalgamation with AOA on 26th September*, since the airline took over not only the latter company's personnel but its entire fleet of aircraft, so that PAA now has over 144 long-range airliners. In addition the management announced on 22nd September that they had ordered another 18 Douglas DC-6B's, which will cost a total of $21,000,000, and are to be delivered within a year.

The completion of the transfer of the assets of AOA to PAA means the "cease fire" in the fierce struggle put up by their American competitors—particularly be TWA—against the merger. The President of the Board of Directors, Warren Lee Pierson, in a last desperate effort, requested that the CAB's decision should not be put into effect until it was certain that the French and British air authorities would agree to the transfer of routes from AOA to PAA. It is true that the Governments of these two States are raising certain objections, since this distinct strengthening of competition to their national trans-Atlantic companies is giving them cause for concern. How long their opposition can and will last is another question. In any case the CAB did not agree to TWA's request. On the question of the Atlantic, PAA has emerged as the victor. At the same time, however, the airline's application for permission to operate inland routes was finally refused. However, since in Juan Ferry Trippe's vocabulary the word "finally" only means "for the time being," the aviation world can expect a fresh call to arms in a few months' time.

A Basic Problem in Rocket Research

Ever since the earliest days of rocket technology—and that means going back a few centuries—improved propellants have been the one unavoidable premise to further progress. It is only a few decades since liquid propellants started to oust the old powder fuels—at first in theory, later in practice. At the present time thousands of liquid propellants are being examined by the Great Powers—weighed and frequently found wanting.

Concerning this extremely important aspect of modern rocket technology, two experts have—simultaneously and independently of each other—expounded their opinions for our benefit. H. Gartmann *places the accent on the operational aspects.* J. Himpan *confines his remarks to propellant performance. Both articles supplement each other and should therefore appear together. Both writers agree that specific gravity, alongside exhaust velocity, has an important effect on rocket propellant performance. It is interesting to note that Himpan maintains that, and gives reasons why, the dissociation of liquid hydrogen by means of nuclear energy can never bring about appreciable increases in rocket performance.* — Ed.

Rocket Propellants

by Heinz GARTMANN

Conventional types of combustion engine use the atmosphere as source of the oxygen they need. In contrast, a rocket motor carries its own supply of all materials necessary for it to function. Rocket motors can be designed in various ways, to serve as sources of auxiliary power for aeroplanes equipped with ordinary engines, as prime movers for ultra-high-speed aircraft and projectiles, or, finally, as the only known means of propulsion through interplanetary space.

In pressurized-gas rockets the propulsive jet is produced through the expansion and subsequent escape of hot gases from a combustion chamber. The speed with which the gases escape, *i.e.*, the exhaust velocity, may be regarded as a criterion for the quality of the propellant and the design of the combustion chamber, exhaust nozzle and general thermodynamic cycle. Problems of propellant composition are intricately interwoven with those of motor design. In the early days of rocket research use was made of propellant mixtures of low calorific value, such as water-diluted alcohols as fuels and hydrogen peroxide as oxidizer. The presence of water in the alcohol reduced the combustion temperature, but simultaneously stepped up the specific consumption (Figs. 1 and 2). At this stage of development, also, such secondary factors as cooling properties frequently played a part in the selection of propellants.

Present-day research is concerned with evaluating different hydrocarbon fuels, hydrogen, liquid oxygen (sometimes fortified with liquid ozone) and various special compounds. Exhaust velocities, which used to attain barely 2000 m/sec., now lie between 3000 and 4000 m/sec. Future experiments will probably involve the heating of the propulsive gas masses by nuclear energy, yielding substantially higher exhaust velocities—over 10,000 m/sec. using hydrogen—without appreciably raising the combustion temperature. In the meantime, research is still concerned with chemical propellants, in which the reactions occur within the electron shells of the atoms and molecules. Table I is a brief survey of technically useful combinations of fuels and oxidizers for propelling rockets. Even this incomplete list serves to show conclusively that the success of rocket motors as prime movers is entirely dependent on the development of improved propellants or better exploitation of the combinations now in use. The search for new propellants is therefore characteristic of modern rocket research. However, discoveries which appear useful in the laboratory often do not fulfil their expectations in field tests. Apart from experimental designs, the big rockets of today are all driven by propellant mixtures which, although born of the present decade, are already labelled " classic mixtures ".

Specific consumption and specific impulse

The first step in designing a rocket motor of specified thrust, duration of function and field of application, is to choose a suitable propellant. The list of possible fuel-oxidizer combinations is endless. A research team at the German Bayerische Motorenwerke, headed by *Helmut von Zborowski*, tried out more than 3000 combinations.

(1) One of the essential requirements is low consumption. In round figures, rocket motors still consume about ten times as much fuel as jet engines. By dividing the propellant weight flow rate $\dot{Q}$ (in kg./sec.) by the thrust S (in metric tons), we obtain the *specific consumption*, as follows:—

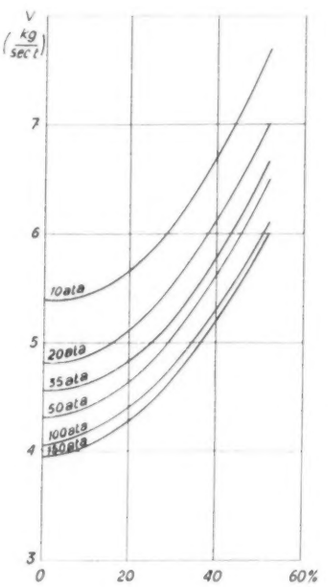


Fig. 1: Water dilution (in percentage of total weight) and specific consumption (V) for nitric acid and alcohol at different chamber pressures and 1 atmosphere counterpressure.

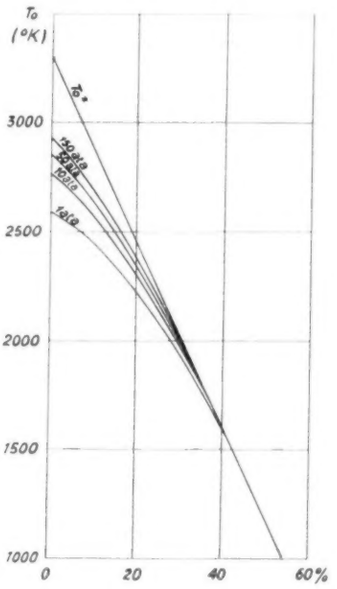


Fig. 2: Water dilution (in percentage of total weight) and chamber temperature (T_0) for nitric acid and alcohol at different chamber pressures and 1 atmosphere counterpressure.

$$V = \frac{Q}{S} \left(\text{in } \frac{\text{kgs}}{\text{tonnes, sec.}} \right)$$

(2) A more conventional expression is *specific impulse*, which indicates the thrust (here in kilograms) produced from a unit weight of propellant per second. The specific impulse is therefore :

$$I = \frac{S}{Q} \text{ (sec.)}$$

George P. Sutton designates this value as the " specific thrust."

(3) The *impulse*, which the Germans usually call " *Schubzeitwert* " (thrust-time value), is the integral of the thrust throughout the duration of combustion (in kg.sec.). If the thrust is constant, it is the product of thrust times combustion duration. This term is primarily used for evaluating expendable missiles, which cannot be re-charged after operation.

(4) Between specific impulse and exhaust velocity of the gases there exists the following relation :

$$I = \frac{c}{g} \text{ (sec.)} \qquad \left(S = \frac{Q}{g} c \right)$$

in which g is gravity. From the measurable specific impulse or consumption we can therefore calculate the exhaust velocity.

(5) If we divide the specific impulse by the propellant *volume* flow rate instead of by the weight flow rate, we obtain :

$$V_d = \frac{Q}{S} \qquad \left(\frac{\text{dm}^3}{\text{tonnes, sec.}} \right)$$

(6) In the same way we may write for the specific impulse :

$$I_d = \frac{S}{Q} \qquad \frac{\text{(kgs.sec.)}}{\text{dm}^3}$$

The index d here stands for density.

Classification of propellants

When classifying liquid rocket propellants it is usual to speak of monopropellant and bipropellant systems. *Monopropellant* systems require no supplementary oxidizer, because they are mixed either from the start with an oxidizer or else because their molecules—mostly unstable—already contain oxygen (*e.g.* nitroglycerine, nitrocellulose). Some of them require the addition of a catalyst before they can ignite ; for example, hydrogen peroxide and calcium permanganate. By way of contrast, *bipropellant systems* consist of a fuel and an oxidizer, which have to be injected separately into the combustion chamber. If they ignite of their own accord when they come into contact with each other, they are called *spontaneously ignitable* (for example, nitric acid and visol); if the combustion has to be initiated by special means, the propellant mixture is *non-spontaneously ignitable* (for example, nitric acid and methanol).

The initial preference was for non-spontaneously ignitable propellants, since in the case of accidental mixture of spontaneously ignitable materials (caused, for example, by a leakage in a conduit), everything is likely to go up in flames. But, whilst non-spontaneously ignitable propellants are far less dangerous, they require an ignition system which may entail certain complications [1], depending on the design of the motor.

[1] Expendable rockets can be set in operation pyrotechnically by powder cartridges or by pre-injecting spontaneously-ignitable liquids contained between membranes. If repeated ignition is desired, use is made of a complete ignition system which feeds, by means of pumps or compressed air, spontaneously-ignitable fluids into the combustion chamber, thereby initiating the combustion of the actual propellant. Ignition failures or traces of propellant in the combustion chamber prior to the ignition operation, cause the entire rocket to blow up. Photo-electric cells reacting to the ignition flame, or pressure switches which are tripped by the slightest pressure in the combustion chamber, are installed to minimise such dangers. Nevertheless, these systems involve risks.

Although the great majority of propellant combinations are non-spontaneously ignitable, the spontaneously ignitable mixtures are gradually receiving more attention. One of the earliest known combinations of this category is that of hydrogen peroxide and hydrazine hydrate. For example, the propellant chosen for the Walter 109-509 motor which powered the Messerschmitt Me 163B fighter consisted of 80% hydrogen peroxide and a mixture of hydrazine hydrate, methanol and water. The oxidizer bore the code name " T-Stoff," and the fuel was known as " C-Stoff." Spontaneously ignitable mixtures are characterized by an ignition delay ; and this should not exceed one tenth of a second. At normal temperatures this delay is short enough to ensure conditions of relative safety. Accidents in conjunction with spontaneously ignitable propellants mostly occur because the two components do not enter the combustion chamber simultaneously. The safest method, therefore, is to inject one of the components a fraction of a second earlier than the other, taking care that this component is not the one which decomposes spontaneously in the presence of the other. In the case of propellant mixtures based on nitric acid it has been found by experience that the fuel should be injected first ; other mixtures require that the oxidizer be injected first.

Oxidizers

The number of possible oxidizers is immense. In reality, however, hydrogen peroxide, nitric acid, liquid oxygen and, of late, liquid ozone have claimed the greatest attention. Whilst nearly all the fuels are easy to handle, the concentrated acids and liquid gases among the oxidizers set many knotty problems.[2]

Concentrated hydrogen peroxide was rarely manufactured until rocket technicians began to use it. Odourless and colourless, it freezes at —2 deg. C. and evaporates slowly at room temperature. For some time it was used on a wide scale in rocket propellants but is now regarded as less useful in view of its low calorific value and tendency towards decomposition. In contrast to the highly diluted bleaching agent available commercially under the same name, the concentrated product is always prone to decomposition. The slightest traces of catalyst—for example, dirt in the tanks—can lead to decomposition of an explosive nature.

Nitric acid likewise possesses a low calorific value, but is stable and more easily stored. It is available as a yellowish liquid which constantly liberates nitrogen oxides.

Its corrosive action on most metals, wood and organic matter is extremely rapid, and produces highly toxic nitric fumes. Its manipulation requires anti-corrosive coated containers and conduits, as well as protective clothing for the personnel. Containers have to be carefully sealed (fig. 3) to minimize the dangers due to escaping fumes. Its desirably high density, 1.5 kg./dm³, makes for conveniently small containers. Other properties favour its use as a constituent of rocket propellants in certain cases.

[2] Alongside oxidizers studies have recently started on a halogen : *fluorine*, which favours strongly exothermic reactions. Liquid fluorine boils at —187 deg. C. and has a density of 1.11 kg./dm³. With hydrogen it is spontaneously ignitable. Since it has hitherto been difficult to obtain, and because it possesses certain undesirable properties, fluorine is only gradually finding its way into rocket technology.

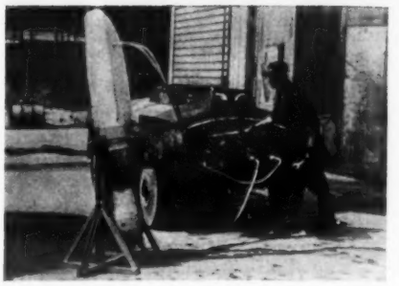


Fig. 3: Fueling with nitric acid by means of a special tank car (for the BMW 109-511 glide-bomb motor).

Liquid oxygen, a light blue liquid of watery consistency, which boils at —182 deg. C. under normal pressure conditions, is difficult to store but nevertheless the most widely used oxidizer in rocket propellants, thanks to its high calorific value (in mixtures) and ready availability (through liquefaction of air). Its main disadvantage, that of quick evaporation, comes to light notably when rockets have to be charged some time ahead of being fired. Also because of its low storage temperature special materials are required for sealings and valves.

Ozone, the tri-atomic form of oxygen, liquifies at —112 deg. C. and, owing to its dangerous tendency to decompose, is used only in dilution with liquid oxygen. Its high calorific value (in mixtures) makes it an extremely attractive oxidizer.

Zborowski, who is credited with having introduced nitric acid into rocket propellant research, carefully studied the merits of hydrogen peroxide, nitric acid and liquid oxygen as oxidizers. Using a hydrocarbon fuel of 10,000 kcal/kg. calorific value, he calculated the specific consumption in each case at a chamber pressure of 35 atmospheres (1 atm. counter-pressure). His investigations bring to light the distinct *advantage of the high specific gravity of nitric acid*, if we consider the consumption per unit volume (Fig. 4). The high density enables a greater load of propellant to be carried for the same structural weight of the tank.

Fuels

The oxidizers can be combined with numerous fuels. Eugen Sänger divides these into three groups : the materials common to the first development phase of chemical bi-

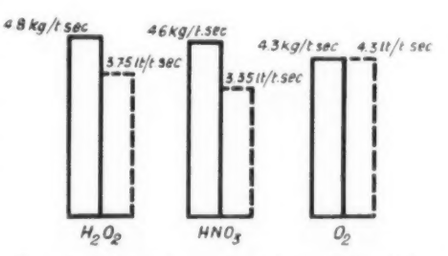


Fig. 4 : Comparison of oxidizers H_2O_2, HNO_3 and O_2 combined with a hydrocarbon fuel of 10,000 kcal/kg calorific value (Zborowski).

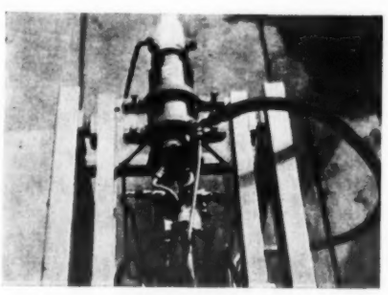
Fuel		Oxidizer			
		H_2O_2	HNO_3	O_2	O_3
Hydrogen	H_2	4630/3990	4570/4210	5640/5210	6095/5710
Octane	C_8H_{18}	4190/3690	3810/3600	4610/4450	5090/4930
Carbon	C	3860/3580	3540/3460	4320/4245	4790/4720
Ethyl alcohol	C_2H_5OH	3980/3580	3700/3480	4400/4200	4840/4650
Methyl alcohol	CH_3OH	3900/3480	3640/3360	4245/3990	4640/4420
Aniline	$C_6H_5NH_2$	3980/3640	3710/3550	4470/4370	4765/4680
Divinyl ether	C_4H_6O	3990/3650	3740/3560	4445/4320	4890/4780
Hydrazine hydrate	$N_2H_4.H_2O$	3960/3530	3760/3430	4280/3970	4610/4330
Aluminium	Al	5030/4180	5070/4220	5730/4820	5970/5110
Beryllium	Be	5800/2630	6020/2220	7050/2740	7310/3370
Lithium	Li	5380/4600	5500/4730	6300/5470	6550/5760
Boron	B	4880/3320	4900/3110	5800/3790	6150/4300
Silicon	Si	4560/ ?	4610/ ?	4250/ ?	5590/ ?
Sodium	Na	3590/2800	3100/2700	3660/2870	3865/3130

TABLE I Theoretical exhaust velocities in metres per second computed from maximum and minimum calorific values of the mixture (according to Dr. E. Sänger).

propellants, such as methanol, ethanol, aniline, hydrazine hydrate ; the group now in the research phase, consisting of hydrocarbon fuels and hydrogen ; and finally such high specific heat elements as beryllium and lithium.

The greatest experience so far gained has been with the first group. Large numbers of tests have been carried out with non-spontaneously ignitable mixtures from this group, for example with different varieties of gasoline, with benzene and benzene derivatives, heavy petroleum fractions, and alcohols (mainly methyl and ethyl alcohol). These alcohols claimed some attention since they burn cleanly without noticeable residue.

Fig. 5 : Test stand for trial run with nitric acid.



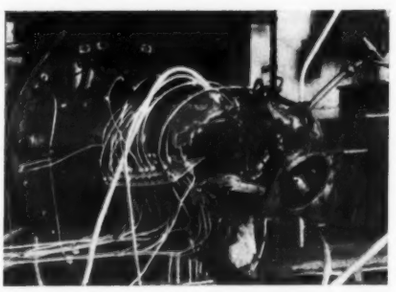


Fig. 6 : Test stand destroyed by explosion due to delayed ignition.

Their low combustion temperature facilitated the earlier experiments. Among the spontaneously ignitable materials, the *amines* are outstanding for their useful ignition properties : *Xylidine*, a mixture of various isomers of dimethyl aniline, and *triethylamine*, a tertiary amine, are two examples of fuels having good ignition and viscosity. The mixture of xylidine and triethylamine was developed by the German BMW concern under the code name " Tonka 250. " Another BMW mixture was " Tonka 505 C," which consisted of 42 parts by weight of spontaneously ignitable materials and 58 parts of non-spontaneously ignitable substances, mostly gasoline and xylene. As further examples of the over 3,000 mixtures prepared and tested by BMW we might mention ortho-toluidine and mesidine as primary phenyl amines, aminodiethyl aniline, methyl pyroline and furfural alcohol.

TABLE II Specific impulse of some bi-propellants
(according to Zwicky and Ross)

Oxidizer	Fuel	I (sec.)	I_d
Hydrogen peroxide	Hydrazine hydrate	200	—
Nitric acid	Furfural alcohol	214	293
Red-fuming nitric acid	Aniline	221	307
Liquid oxygen	Ethanol + 25% water	239	237
Liquid oxygen	Ethanol	243	235
Liquid oxygen	Liquid hydrogen	358	101 (!)

(I_d = specific impulse based on English units.)

Bi-propellant combinations

Table I is confined to a list of to-day's most important bi-propellant systems, indicating for each the theoretical exhaust velocity attainable if the upper and lower calorific values are converted completely into kinetic energy. In practice, of course, it is never possible to accomplish a complete conversion. The internal efficiency (ratio of the squares of the practical and theoretical exhaust velocities) is nowadays between 30 and 50 per cent, though technical progress in design may yet bring forth improvements in this respect. In Table II, which is taken from a report by *Zwicky and Ross* [3], the internal efficiency is taken into account. Here a very good illustration is given of the importance of the *specific gravity*. The specific impulse per unit volume affects the dimensions and weight of the rocket. The value I_d consequently represents an excellent criterion for performance evaluation. In Table II it lies between 235 and 307 in all cases except for the combination of liquid hydrogen and liquid oxygen. This difference is so slight that other properties of the materials frequently play a bigger part in the selection, such as for example the molecular weight of the combustion products, the availability, toxicity, explosion and fire hazards, feed conditions, storage characteristics, ignition properties, behaviour during preparation, etc.

The preparation of the propellants takes place in the rocket combustion chamber. First, the mixing operation takes place. It consists of a complicated sequence of physical and chemical processes, such as injection, atomization of the spray, droplet formation, turbulent mixture and ignition, which are all governed by the design of the feed and combustion components. These problems are much the same for all the oxidizers. Then, combustion causes the formation of carbon dioxide, steam, nitrogen and such decomposition products as hydrogen, oxygen, carbon monoxide, nitric oxide, etc. If the conditions of mixture preparation are incorrect, black clouds come out of the exhaust nozzle (in place of a clearly defined jet), thus providing visual evidence of this condition.

J. Stemmer maintains that liquid propellant rockets will probably be obsolete by the time interplanetary flight becomes feasible. For this purpose studies are being made of how to utilize nuclear energy. The idea is to heat to the point of dissociation masses of 100 molecular weight, as for example hydrogen, whereby exhaust velocities ranging from 10,000 to 20,000 metres per second should result. The theoretical exhaust velocity of monatomic hydrogen—following the dissociation of liquid H_2 by nuclear energy—has been computed by Dr. Sänger as 20,800 metres per second. The possibility of utilizing cosmic energy for travelling through interplanetary space is also admitted.

[3] " Nitromethane as a Monopropellant " by F. Zwicky and C. C. Ross. Society of Automotive Engineers, New York, 1949.

Evaluating Rocket Propellant Performance

by Joseph HIMPAN, Paris

Writers frequently make the error of judging rocket propellants solely by the exhaust velocity they can produce. Only rarely do they mention a propellant's specific gravity as having any influence, and then without elaborating to any great extent on the reasons why. In the present article we shall endeavour to show that rocket propellant performance is governed by three factors :

1) exhaust velocity w
2) average specific gravity of propellant d_m
3) rocket design index σ

We shall develop a simple formula for evaluating propellant performance and use practical examples to show that certain rocket propellants commonly thought to be the best because they produce high exhaust velocities are actually quite low-performance types.

Rockets are judged by only one criterion : the altitude or range they can attain. If a number of identical rockets—all having the same net weight, propellant capacity, payload and chamber pressure—are fired with different propellants, it follows that the highest performance propellant will be the one which endows its rocket with the greatest range. But, as the following example shows, this particular propellant need not necessarily have produced the highest exhaust velocity.

Comparison between two single-stage rockets

Imagine two V2 rockets which are absolutely identical. One is filled with liquid hydrogen and liquid oxygen, the other with ethanol (95 %) and nitric acid. It is assumed that each of the identical propulsion systems is utilizing its respective propellant mixture to the best advantage. Each rocket features a combusion chamber pressure of 16 atmospheres, an exit pressure of one atmosphere, a propellant capacity of 9090 litres and an empty weight plus payload of 3900 kilograms.

The liquid hydrogen and liquid oxygen are mixed in the ratio giving the highest exhaust velocity ($m = 0.3$). This signifies an average specific gravity $d_m = 0.251$ (Fig. 1) and a propellant weight equal to $0.251 \times 9090 = 2280$ kgs. By substituting these values in the general rocket equation we obtain the following ideal velocity at power cut-off:[1]

$$V = 2795 \ln \frac{2280 + 3900}{3900} = 1290 \text{ m/sec.}$$

(average effective exhaust velocity $w = 2795$ m/sec.)

The ethanol and nitric acid are mixed in a ratio of 0.32. The average specific gravity of 1.26 enables us to compute the propellant weight as $1.26 \times 9090 = 11{,}450$ kgs. The ideal velocity at power cut-off works out at

$$V = 1645 \ln \frac{11{,}450 + 3900}{3900} = 2260 \text{ m/sec.}$$

(average effective exhaust velocity $w = 1645$ m/sec.)

The velocity at power cut-off is 75 % greater in the second example ! And this despite the fact that the tanks were assumed to be full in each case—which is possible only with propellants *not* at boiling point, thus with ethanol and nitric acid but not with liquid hydrogen and liquid oxygen.

We might now ask whether the velocity at power cut-off could not be substantially altered if each rocket were adapted to its particular propellant, since the total weight would be far smaller in the case of the first rocket. The answer would be that the payload is in any case imposed from the start ; the rocket shell and its tanks can hardly be modified, for mechanical reasons ; furthermore, since both rockets have to withstand the same aerodynamic forces, they must have the same structure. The only features which can be altered—though not in favour of the H_2/O_2 mixture—are the propellant feed system and the combustion chamber. Thus it is seen that the structural weight of a rocket is virtually independent of the propellant used. This statement is also valid for other chamber pressures, since all weights and performance values vary in the same sense.

We may therefore conclude that a propellant composed of a mixture of ethanol and nitric acid is " technically " of higher performance than a mixture of liquid H_2 and liquid O_2. Presupposing two rockets of identical design, the former mixture will provide the greater range.

The general index of performance

In evaluating rocket propellants we shall begin with the fundamental rocket equation, viz. :

ideal velocity at power cut-off

$$v = w \ln \frac{G_a}{G_e} \qquad (1)$$

The higher the ideal velocity at power cut-off, the higher the performance of the rocket. Though this equation does not take into account the influences of terrestrial gravity and air drag, these may be ignored since we are concerned only with drawing comparisons. If we transform this equation in such a way that the characteristic values for the propellants are evidenced, it follows that we shall obtain a basis for correctly evaluating rocket propellant performance. The propellant giving the highest value for v is naturally the best one.

Now, the initial total launching weight G_a is equal to the sum of the weight of the propellant T, empty rocket K and payload N. The end weight G_e is represented by the sum of K and N. The weight of propellant is given by the product of tank capacity V and average specific gravity d_m. We may therefore write :

$$v = w \ln \frac{G_a}{G_e} = w \ln \left(1 + \frac{T}{K + N}\right) = w \ln \left(1 + d_m \frac{V}{K + N}\right)$$

By calling the factor $V/(K + N)$ the " design index " and giving it the symbol σ we may write

$$v = w \ln (1 + d_m \sigma) \qquad (2)$$

In this way we have obtained the simplest form of equation for evaluating rocket propellant performance in the case of single-stage designs. Of the three parameters w, d_m and σ, the first two characterize the propellant, whilst σ pertains to the design of the rocket. When comparing various propellants it is logical that we should presuppose a constant value for σ and a constant chamber pressure in every case. If σ is always the same it signifies that each rocket is of practically the same size. In principle, the question of the kinds of propellant used and their specific gravity is but of secondary interest. We are mainly interested in attaining the maximum velocity at power cut-off. For a given rocket, therefore, the highest-performance propellant is the one which, by equation *(2)*, gives the highest value for v. Hence, the " technical " performance of a rocket propellant is not dependent solely on its exhaust velocity or specific impulse, but also on its specific gravity and the rocket design index.

A propellant producing a lower exhaust velocity but having a higher specific gravity may be superior to one producing a higher exhaust velocity but having a lower specific gravity. Moreover, a propellant which has been found to be the best for certain rocket designs may be less suitable in rockets having different design indices. As regards the latter consideration, however, we shall see later that the influence of the design index, seen in the light of present-day technical progress, is relatively small. Exhaust velocity and specific gravity count most.

In the case of *multi-stage rockets*, the velocity at power cut-off of the last stage rocket—and with it, the performance index of the propellant—is given by the sum of the velocities pertaining to the individual stages, viz. :

$$v = w_1 \ln (1 + d_{m1} \sigma_1) + w_2 \ln (1 + d_{m2} \sigma_2) + \cdots + w_n \ln (1 + d_{mn} \sigma_n) \qquad (3)$$

This equation may be simplified by supposing that each stage is charged with the

[1] The velocity which the rocket would obtain in empty, gravity-free space after consuming all its propellant.

Stage	Empty weight (K) kgs	Payload (N) kgs	Propellant capacity (V) litres	Propellant weight (T) kgs	Exhaust velocity (w) m/sec	Propellant spec. grav. (d_m) kg/litre	Design index σ litre/kg	Velocity at power cut-off (v) m/sec
Propellant : gas oil/tetranitromethane								
I	50	10	200	300	2 800	1.50	3.33	5 000
II	500	360	2 000	3 000	2 800	1.50	2.32	4 200
III	5 000	3 860	20 000	30 000	2 160	1.50	2.26	3 190
Total	5 550	—	22 200	33 300	—	—	—	12 390
Propellant : liquid H_2/liquid O_2								
I	50	10	200	85	3 650	0.425	3.33	3 210
II	500	145	2 000	850	3 650	0.425	3.10	3 070
III	5 000	1 495	20 000	8 500	3 650	0.425	3.08	3 060
IV	50 000	14 995	200 000	85 000	2 860	0.425	3.08	2 400
Total	55 550	—	222 200	94 435	—	—	—	11 740

TABLE I

same propellant, e.g. to avoid technical complications. We may then write :

$$v = w \ln [(1 + d_m \sigma_1)(1 + d_m \sigma_2) \cdots (1 + d_m \sigma_n)] \qquad (4)$$

Presupposing an identical design index for each rocket stage, the equation takes on a further simplified form :

$$v = w \ln (1 + d_m \sigma)^n = n\, w \ln (1 + d_m \sigma) \qquad (5)$$

In this way we obtain the performance index of an n-stage rocket whose individual stages all have the same design index and are charged with the same propellant. It is merely the n-fold performance index of a single-stage rocket having the same design index. We may therefore state that, if a propellant is the best available for a single-stage rocket, then it also constitutes the best choice for a multi-stage type, provided the design index remains constant.

Comparison between two multi-stage rockets

The following example also serves to show the tremendous influence of the propellant's specific gravity on rocket performance. It is required to accelerate a 10-kg. payload with a multi-stage rocket to a velocity of 12,000 m/sec. Instead of having the same design index (σ) throughout, we pre-suppose that the ratio of propellant capacity to empty weight is always 4 liters per kilogram. Lighter weight propellants will therefore produce higher design indices for all stages except the final one (cf. Table I), a circumstance which the designer must bear in mind from the start. Investigation will now be made of propellants comprising mixtures of gas oil and tetranitromethane, and liquid hydrogen and liquid oxygen, at 20 atmospheres chamber pressure, mixed in the stoichiometric ratio and an exhaust pressure of 0.8 atmosphere for the stage working within the earth's atmosphere, and 0.1 atmosphere for the remaining stages. The results obtained through substitution in equation (3) are given in Table I.

This comparison serves to show that a propellant composed of gas oil and tetranitromethane requires only a *three*-stage rocket of 38,860 kgs., whilst the liquid oxygen and liquid hydrogen mixture calls for a *four*-stage design of 149,995 kgs. initial weight—notwithstanding the fact that the latter mixture produces a substantially higher exhaust velocity.

The specific performance index

We shall now indicate a method for evaluating rocket propellant performance which ignores the rocket design index and is handier for practical purposes. Let us first examine Figs. 1 to 5, which show how the average specific gravity (d_m) of the propellant, the exhaust velocity (w) and the velocity at power cut-off (v) vary with the mixture ratio of fuel to oxidizer.

Figs. 3 to 5 are based on rocket design indices of 0.1, 1.0 and 5.0. It is seen that, although the absolute velocities at power cut-off change, their curves have the

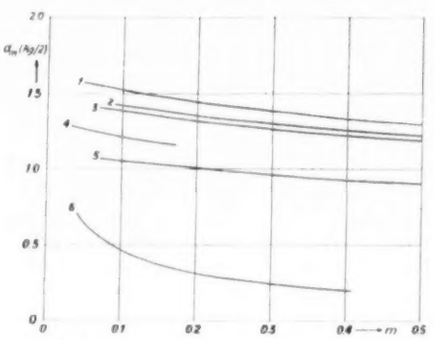


Fig. 1.

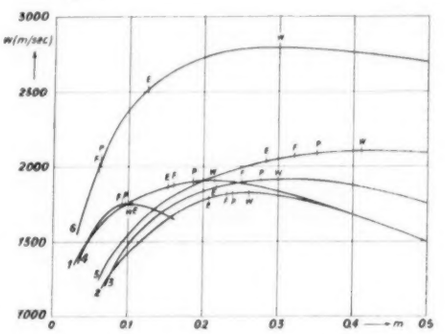


Fig. 2.

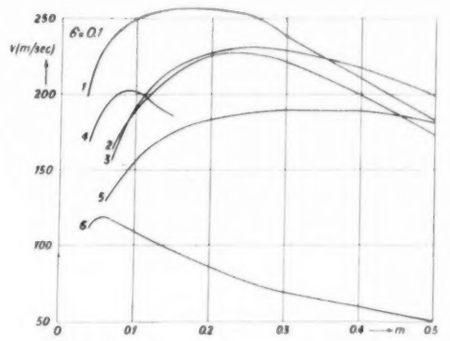


Fig. 3.

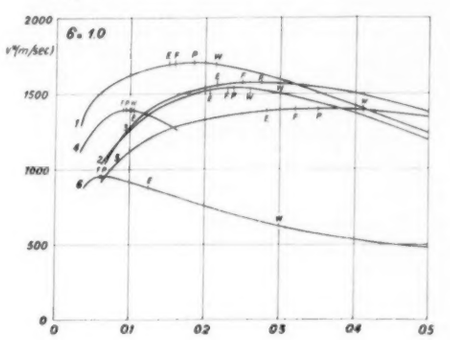


Fig. 4.

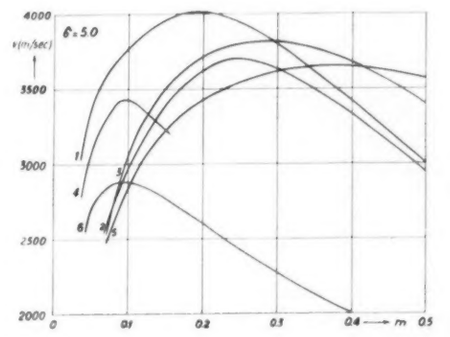


Fig. 5.

Figs. 1-5 : Average specific gravity (d_m), *effective exhaust velocity* (w) *and ideal velocity at power cut-off* (v) *plotted versus mixture ratio* (m) *for a number of rocket propellant combinations. The ideal velocity at power cut-off* (v) *for a given rocket design index (Fig. 3 :* $\sigma = 0{,}1$ *litre/kg. Fig 5 :* $\sigma = 5.0$ *litres/kg) represents the* general *performance index ; the same relation for* $\sigma = 1.0$ *(Fig. 4) represents the* specific *performance index. The studies are based on* 16 *atm. chamber pressure,* 1 *atm. exhaust pressure and* $w = 0.85\ v_{th}$.

I Gas oil/Tetranitromethane
II Benzene/Nitric acid
III Trimethyl benzene/Nitrogen peroxide
IV Butane/Hydrogen peroxide
V Hexane/Liquid O_2
VI Liquid H_2/Liquid O_2
E Stoichiometric mixture ratio
P Optimum performance mixture ratio
W Mixture ratio yielding highest exhaust velocity
F Mixture ratio yielding lowest volume flow

same slope. It therefore seems fitting to reduce the general performance index (equation 2) to a *specific performance index*, the sole purpose of which is to enable us to make an initial comparison between the propellants and determine the optimum mixture ratio (maximum technical performance) for each of them. By making the rocket design index equal to unity we can write:

$$v^* = w \ln (1 + d_m) \qquad (6)$$

This equation has been checked and shown to be valid for design indices between 0.1 and 5.0 as well as for almost all utilizable propellants. Design indices exceeding 5.0 are hardly to be expected for some years to come.[2]

The next step is to "normalize" this specific index. Advantageous and practical standard values would be: 20 atmospheres chamber pressure, 1 atmosphere exhaust pressure, the theoretical exhaust velocity v_{th} and the stoichiometric ratio of fuel to oxidizer. The optimum mixture ratio is of course indicated by the apex of the v^*-curve in Fig. 4 and differs somewhat from the stoichiometric mixture (which is important in bench tests). This difference is substantial only in the case of liquid O_2/ liquid H_2, when the optimum mixture ratio leans strongly towards the oxygen (and, oddly, the mixture for maximum exhaust velocity yields the lowest performance). Table II lists a number of propellants in order of performance (according to equation 6 and the standard values mentioned above). The effective exhaust velocity (and the performance index) is about 0.85 times the theoretical value.

[2] The German V-2 had only 3.13 litres propellant capacity per kg. empty weight: the U.S. "Viking" rocket carries 3.73 litres per kg.

TABLE II (20 atm. chamber pressure, 1 atm. exhaust pressure, stoichiometric propellant ratio)*

Fuel	Oxidizer	Spec. grav. (d_m) kg/litre	Cal. value (H_T) kcal/kg	Theor. exhaust velocity (wv_{th}) m/sec	Chamb. temp. (T_t) deg. K	v^*_{th} m/sec
Dibenzylamine	Tetranitromethane [1]	1.520	1670	2215	3215	2045
Aniline	Tetranitromethane	1.502	1640	2210	3195	2025
Gas oil	Tetranitromethane	1.505	1590	2190	3165	2010
Dibenzylamine	Nitric acid 60/40 [2]	1.466	1575	2220	3105	2000
Bromobenzene	Tetranitromethane	1.610	1450	2065	3205	1978
Aniline	Nitric acid 60/40	1.452	1535	2205	3080	1975
Gas oil	Nitric acid 60/40	1.450	1472	2180	3035	1950
Dibenzylamine	Nitrogen peroxide [3]	1.365	1720	2250	3205	1933
Bromobenzene	Nitric acid 60/40	1.580	1320	2040	3095	1930
Aniline	Nitrogen peroxide	1.357	1680	2245	3180	1920
Ethanol (95%)	Tetranitromethane	1.370	1525	2210	3055	1905
Dibenzylamine	Nitric acid [4]	1.390	1475	2185	3035	1896
Gas oil	Nitrogen peroxide	1.350	1615	2220	3140	1893
Aniline	Nitric acid	1.378	1440	2175	2920	1879
Bromobenzene	Nitrogen peroxide	1.485	1432	2060	3195	1874
Gas oil	Nitric acid	1.372	1375	2140	2965	1843
Bromobenzene	Nitric acid	1.497	1240	2010	3025	1840
Ethanol (95%)	Nitric acid 60 40	1.295	1400	2185	2920	1813
Ethanol (95%)	Nitrogen peroxide	1.218	1530	2240	3005	1781
Dibenzylamine	Hydrogen peroxide [5]	1.302	1217	2115	2680	1759
Aniline	Hydrogen peroxide	1.295	1195	2100	2665	1742
Dibenzylamine	Liquid O_2	1.105	2275	2345	3455	1742
Ethanol (95%)	Nitric acid	1.260	1310	2140	2850	1740
Aniline	Liquid O_2	1.100	2205	2350	3415	1740
Gas oil	Liquid O_2	1.087	2150	2350	3385	1730
Bromobenzene	Hydrogen peroxide	1.372	1083	2000	2670	1724
Gas oil	Hydrogen peroxide	1.290	1150	2070	2625	1712
Bromobenzene	Liquid O_2	1.255	1800	2100	3440	1704
Ethanol (95%)	Liquid O_2	0.998	1970	2420	3190	1670
Ethanol (95%)	Hydrogen peroxide	1.215	1125	2060	2570	1635
Liquid H_2	Tetranitromethane	0.722	2010	2530	3060	1372
Liquid H_2	Hydrogen peroxide	0.743	1445	2325	2620	1288
Liquid H_2	Nitric acid 60/40	0.608	2010	2600	2950	1230
Liquid H_2	Nitric acid	0.605	1885	2545	2885	1207
Liquid H_2	Nitrogen peroxide	0.571	2200	2680	3030	1207
Liquid H_2	Liquid O_2	0.425	3050	3015	3185	1068
Liquid H_2 Nuclear energy	—	0.070	approx. 15000	7140	2760	483

[1] Tetranitromethane $C(NO_2)_4$
[2] Nitric acid 60/40 60% HNO_3+40% N_2O_4
[3] Nitrogen peroxide N_2O_4
[4] Nitric acid HNO_3
[5] Hydrogen peroxide 80% H_2O_2+20% H_2O

Most propellant mixtures require the addition of certain auxiliary substances, for example to delay ignition and improve combustion. These are not allowed for in Table II. However, their omission does not falsify the essential significance of the table.

The reader will note that propellants using liquid oxygen appear low down in the list, and those employing liquid hydrogen as fuel even lower. The least effective of all the propellant mixtures is the liquid H_2/liquid O_2 combination.

Surprisingly, the much vaunted liquid H_2/nuclear energy combination, of which so much is expected, cannot compare, in performance, even remotely with any of the common propellant mixtures used at present, if we judge it on the basis of the chamber temperatures permissible today. Indeed, it is even very much inferior to the low-performance liquid H_2/ liquid O_2 mixture.

It might be argued that the utilization of liquid H_2, in view of its extremely low specific gravity, would enable the same rocket construction to take on a higher design index. However, this is a fallacy. To begin with, a hydrogen rocket, like any other, needs propellant tanks, a feed system, a Laval duct, control devices, and so forth. Since a pressurized gas is used for injecting the propellant, it is evident that a higher design index is unattainable, as there is no structural economy compared with other rocket types. On the contrary, there will be the extra weight of the nuclear energy installation. If, by using a pump feed system, weight were to be saved by building the shell and tanks somewhat lighter, this economy would again be offset completely by the inevitable losses of liquid hydrogen due to evaporation. If, on the other hand, one were to restrict this evaporation by installing some form of thermal insulation, then the structural weight would again be increased, causing a corresponding drop in design index value. It is therefore evident that no improvement in the rocket design index can be brought about by a liquid hydrogen and nuclear energy propellant combination. Consequently, we may state that no increase in rocket performance is to be expected from this "fuel of tomorrow."[3]

* Compared with the figures calculated by Sänger from the upper and lower calorific values (p. 529) the theoretical exhaust velocities given here are appreciably lower. On the other hand, Himpan recommends a velocity factor (w/w_{th}) of 0.85, whilst this, according to Gartman, amounts to only $\sqrt{}$ 0.30 to $\sqrt{}$ 0.50 for Sänger's figures. In consequence, the differences in **effective** exhaust velocity, as given by both sources, are not excessively large.—Ed.

[3] There has recently been some talk of using a mercury/nuclear energy combination: cf. W. Ley: "The Shape of Ships to Come" in this issue. (Ed.)

The Interplanetary Ocean

by Professor Werner SCHAUB, Ferndorf bei Siegen

The interplanetary ocean which we propose to navigate is the vast space far beyond the atmosphere of our planet. Materially speaking, it is empty in every sense of the word. In point of fact, an even distribution of all matter in the *finite* universe would result in a substratum of inconceivably low density, of the order of 10^{-30} gr./cm³ or roughly 1 proton per cubic metre.

Physically speaking, however, interplanetary space is not empty. It is filled with the interaction of masses; in other words, the action of universal gravitation. But let there be no mistaken idea on this point: the words "it is filled" refer to nothing physical. An empty space is a mathematical concept, which has, however, neither rhyme nor reason from a physical point of view. We cannot assume an empty space and attempt to fill it with something afterwards. Hence, we shall not regard interplanetary space as an empty space filled with matter and its effects, but as *a space defined and limited by the masses located in it.* It is these masses which, by their gravitational influences, determine the physical structure of this space, giving it its form and properties.

If man wishes to travel by rocket through this space—or even have unmanned rockets traverse it—he should first of all acquaint himself with its structure. Just like anybody who plans a journey over land or sea, he will need a chart showing him his position, his destination, the way there and the way back. Whilst there may be no harm in going off into the blue here on earth, we short-lived humans ought to think twice before taking a happy-go-lucky trip into interplanetary space. An eternity might elapse before we ever set foot on terra firma again! In the paragraphs which follow, therefore, we shall attempt to construct a chart of a part of the universe surrounding two masses, for example the Sun and the Earth.

*

Masses are singular points in the field of gravity, which have the nasty habit of tugging violently at everything which happens to be near to them. Our first assignment, therefore—and this is the part which is technically most difficult—will be to place as much distance as possible between ourselves and these points. To do this we know of only one method: *to start with a high initial velocity.*

The simplest way to find out what conditions must be fulfilled in order to attain a great altitude upon *taking off from the Earth* is to resort to the Law of Conservation of Energy which can be written as a differential equation thus:

$$\mp d\,(\tfrac{1}{2}v^2) = \pm d\left(-f\frac{m}{r}\right) \qquad (1)$$

where $f = 6.67 \times 10^{-8}$ dynes cm²/g² is the gravitational constant, m the mass of the Earth, and r the distance of the moving body from the centre of the Earth at a given time.

Equation *(1)* reveals that the decrease in kinetic energy of the moving body of mass μ, which we shall assume here to be unity, is equal to the increase in potential energy; and vice versa. At a distance r from the mass m, the potential energy is

$$E_p = \int_r^{\infty} -f\frac{m}{r^2}\,dr = -f\frac{m}{r} \qquad (1a)$$

As the integral reveals, it is defined by the work which is required to displace against terrestrial gravity a mass equal to unity from a point at a distance r from the Earth's centre to infinity. The greater the distance r, the smaller the amount of work required, the latter being at a maximum when the mass is located on the Earth's surface. On the other hand, the greater the altitude at which a body is located, the greater its potential energy, simply because the greater the distance through which it has to fall, the greater will be its kinetic energy upon contact with the Earth's surface. But equation *(1)* shows that the potential energy of a body located at a distance equal to infinity attains a maximum value of zero, which means that any value for the potential energy of a body at a finite distance must be preceded by a minus sign.

By integrating equation *(1)* we obtain the Law of Conservation of Energy in the form

$$\tfrac{1}{2}v^2 + \left(-f\frac{m}{r}\right) = C \qquad (2)$$

which states that the sum of kinetic and potential energy is constant, on condition, of course, that the body receives no additional energy (for example, in the form of rocket thrust). The integration constant (C = total energy) is determined when, at any point along the trajectory, we know the velocity v of the body relative to m, and its distance r from the Earth's centre. The value of C is therefore determined by the initial velocity v_0 of take-off from the Earth's surface, at a distance r_T from the Earth's centre. Consequently, if v_0—and therefore C—are given, we can calculate the body's distance from the Earth's centre for any other velocity v. Using equation *(2)* this amounts to:

$$r = \frac{2fm}{v^2 - 2C} \qquad (3)$$

The greatest attainable altitude—*i.e.*, the greatest attainable range—is at the point on the trajectory when the kinetic energy is equal to zero, *i.e.* when $v^2 = 0$:

$$r_{max} = -f\frac{m}{C} \qquad (4)$$

This range is infinitely great when $C = 0$. In this case—and solely in this case— the kinetic energy is equal to the potential energy at that point (equation 2) and their sum equals zero. This could not be otherwise, since if the kinetic energy is less than the potential energy—which would result in their sum C being negative—the body would never escape from the Earth's field of gravity but would simply attain a finite altitude or describe an ellipse. If absolute escape from the Earth is desired, then the rocket must have a velocity v_0 at power cut-off such that its total energy C is equal or superior to zero. According to equation *(2)*, we should get $v_0^2 \geq 2\,fm/r_T$. With regard to the Earth we have the numerical values $m = 6 \times 10^{27}$ mass-grams and $r_T = 6.38 \times 10^8$ cms. Hence,

$$v_0^2 \geq \frac{2 \times 6.67 \times 6}{6.38}\,10^{11} = 1.255 \times 10^{12}\ (\text{cm.}^2/\text{sec}^2)$$

so that

$$v_0 \geq 11.2\ (\text{km./sec.})$$

The right-hand factor of equation *(4)* contains only constants. Therefore, for a given initial velocity, the curves of greatest range are *concentric circles about the Earth's centre*, in the plane of a Great Circle. If a radial departure is made from the Earth, the same altitude will always be attained for a given initial velocity, regardless of the direction of departure into space. Equation *(4)* gives the ceiling ($v^2 = 0$); therefore, with a given initial velocity v_0—*i.e.*, for a total energy C which is constant—all the points within the circle can be reached but none of the points outside the circle. Equation *(4)* consequently limits the region in which one can travel with a given initial velocity. Within the circle, the body's kinetic energy is always positive and becomes equal to zero on reaching the periphery; outside the circle, v^2 is negative and the velocity v consequently becomes imaginary. Therefore, there is no possibility of motion.

The above considerations apply only to ranges which are small in relation to the Earth's radius. For greater altitudes, our equations would be valid only on the condition that space contained no celestial bodies other than the Earth. But we are already attempting to take off from a space station named "Earth," which travels at the substantial velocity of 30 km./sec. round the Sun in its gravitational field on a roughly circular orbit. In consequence, it is evident that it is not immaterial whether we start off towards the Sun or away from it, for in the first case the Sun would have an accelerative effect on the body and in the second a delaying effect. A greater ceiling will therefore be attained in the first case than in the second, the difference increasing, the further the body is away from the Earth. The region which we may explore following a departure from the Earth at a given initial velocity is no longer circular but pear-shaped.

Our next step must be to decide on a system of axes on which to record the velocity. As long as we consider the Earth as centre of gravity, then the velocity should be plotted on a system of axes with its origin at the centre of the Earth. But

if we wish to take the Sun's influence into account, then we must realize that we are situated in a rotating disc which revolves about the Sun—or about the centre of gravity of the Sun-Earth system—at the same angular velocity as the Earth. Our choice will therefore lie in a system of axes having its origin at the centre of the Sun—or at the centre of gravity of the Sun-Earth system—its x-axis always coinciding with the line joining the Sun and Earth. The fact that we make our departure from the Earth justifies this *rotating system*, since we have the Earth's peripherical velocity from the start and shall always keep it. In this system of axes, a given point will have a velocity equal to zero when it is displaced perpendicularly to the line connecting it with the Sun, at the angular velocity of the rotating disc.

This system of axes is presented diagrammatically in Fig. 1, whereby M denotes a very large mass (the Sun), m a smaller mass (the Earth) and μ a mass (a rocket) which is negligible in comparison with M and m. The mass m describes a circle about M at a distance R = constant ; μ is situated in the plane of this circle, at a distance R_M from M and R_m from m. Being extremely small, μ can exert no influence whatever on the rotation of m about M. However, the motion of μ is certainly influenced by the masses M and m.

In the rotating system of axes described above, the kinetic energy of μ is at all times given by the equation :—

$$v^2 = f\,\mathrm{M}\left(\frac{2}{R_M} + \frac{R^2_M}{R^3}\right) + f\,m\left(\frac{2}{R_m} + \frac{R^2_m}{R^3}\right) - C_o \qquad (5)$$

This equation, which we shall not develop here, takes on the form of equation *(2)* when μ is located near m. In that case R_M and R are very great in relation to R_m ; moreover, R_M is almost equal to R. In equation *(5)*, therefore, we may ignore the first term (with M) in relation to the second, whereby the latter's term R^2_m/R^3 becomes negligibly small, so that

$$v^2 = 2f\frac{m}{R_m} - C_o \qquad (5a)$$

The velocity v at any point R_M, R_m is still defined here by the constant C_o. This also applies to the initial velocity v_o, which is necessary at the surface of m ($R_M = R$) if a body is to pass through the point R_M, R_m at a velocity v. The maximum altitude or range ($v^2 = 0$) is given by the equation

$$fM\left(\frac{2}{R_M} + \frac{R^2_M}{R^3}\right) + fm\left(\frac{2}{R_m} + \frac{R^2_m}{R^3}\right) = C_o \qquad (6)$$

Since the total energy C_o at the take-off can be given any value—depending on the velocity at power cut-off—equation *(6)* yields an infinite family of curves, exactly as equation *(4)* gives an infinite family of concentric circles. But the curves resulting from equation *(6)* are not normally circles, except when approximation *(2)* is satisfied, *i.e.*, for very small values of R_M or of R_m, hence in the vicinity of M or m. These curves become circles again once R_M and R_m exceed certain values. The two terms in parentheses in equation *(6)* then become equal and the first term in each parenthesis becomes negligible in relation to the second. If μ is located at a very great distance from masses M and m, everything proceeds as though the body were rotating about a single mass $M+m$.

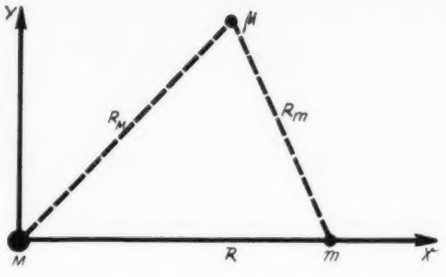


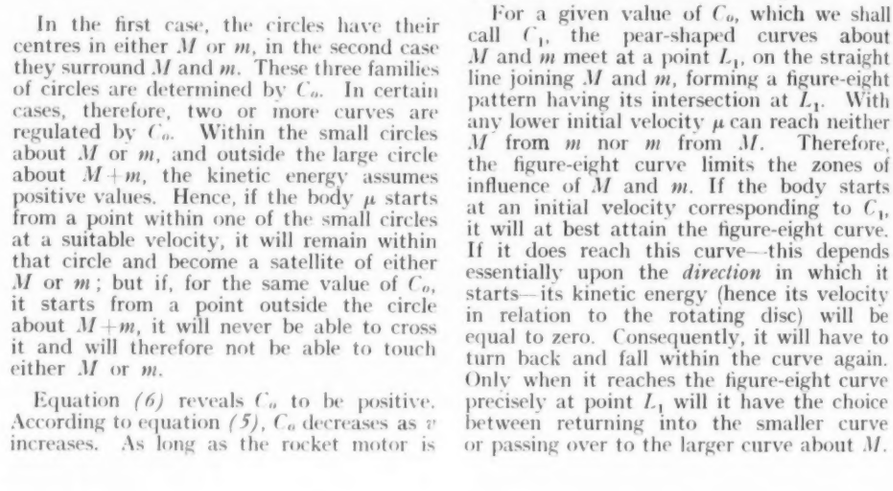
Fig. 1 : The spaceship (μ) *forms with the Sun* (M) *and the Earth* (m) *a system of three masses ; μ is located in the plane of rotation of* m *about* M, *and the abscissae and ordinates of the system of axes are assumed as rotating.*

In the first case, the circles have their centres in either M or m, in the second case they surround M and m. These three families of circles are determined by C_o. In certain cases, therefore, two or more curves are regulated by C_o. Within the small circles about M or m, and outside the large circle about $M+m$, the kinetic energy assumes positive values. Hence, if the body μ starts from a point within one of the small circles at a suitable velocity, it will remain within that circle and become a satellite of either M or m ; but if, for the same value of C_o, it starts from a point outside the circle about $M+m$, it will never be able to cross it and will therefore not be able to touch either M or m.

Equation *(6)* reveals C_o to be positive. According to equation *(5)*, C_o decreases as v increases. As long as the rocket motor is functioning, C_o decreases, attaining its final "minimum" only at power cut-off. Subsequently this minimum value determines the trajectory of μ in that it restricts the range of the rocket (provided that the motor is not re-started). At low initial velocities, *i.e.*, high values of C_o, the ranges over which a rocket can travel, starting from m, are limited by circles about m. At higher initial velocities, a rocket starting from m in direction of M can travel farther than if it starts in the opposite direction. The circles about m become *pear-shaped*, having their elongations pointing in the direction of M. Similarly, trajectories following departures from M reveal the same shape, with their elongations directed towards m. These circumstances are illustrated in Fig. 2.

For a given value of C_o, which we shall call C_1, the pear-shaped curves about M and m meet at a point L_1, on the straight line joining M and m, forming a figure-eight pattern having its intersection at L_1. With any lower initial velocity μ can reach neither M from m nor m from M. Therefore, the figure-eight curve limits the zones of influence of M and m. If the body starts at an initial velocity corresponding to C_1, it will at best attain the figure-eight curve. If it does reach this curve—this depends essentially upon the *direction* in which it starts—its kinetic energy (hence its velocity in relation to the rotating disc) will be equal to zero. Consequently, it will have to turn back and fall within the curve again. Only when it reaches the figure-eight curve precisely at point L_1 will it have the choice between returning into the smaller curve or passing over to the larger curve about M.

Fig. 2 : Curves of maximum range of a spaceship in the rotating system Mm *(Sun-Earth), when* M = 10 m *and* R = 1. *Numerical values indicate* C_o/f*—values for each curve.*



However, it will do neither of these things, since L_1 is a point of equilibrium, which we shall call a *centre of liberation*; and should the body reach this point, it will remain there, with a velocity of zero in relation to the system of axes. It will gravitate about M as if it were connected rigidly to M and m, and will stay at L_1 eternally, in an extremely stable position. *The point L_1 may therefore be regarded as a spot empty of all matter, where it would be possible to "land" without risk and stay any length of time without using up energy.* If the universe contained but the Sun and the Earth, and no other satellites, not even the Moon, then L_1 would be situated at some 1,530,000 kilometres from the centre of the Earth, between the Earth and the Sun [1].

If we wish to start from m and escape from its zone of influence, we must start with a value of C_o less than C_1. In this case, the figure-eight curve would "open" at L_1 and turn into an hour-glass curve without a point of intersection. The whole region enclosed by this curve, including $M + m$, is now accessible. For each value of C_o exceeding C_1 we obtain three "ovals"—one around M, one around m, and one around $M + m$. *Within the figure-eight curve and outside the large oval, the kinetic energy v^2 is positive and the velocity is expressed in real values.*

Between these curves, however, v becomes imaginary. Hence it follows that, starting from within the figure-eight curve or outside the large oval with an initial velocity corresponding to C_1, it would be impossible to cross this space. In order to do so, it would be necessary to start with a smaller value for C_o. A certain value C_2 yields the dented oval II about M and m, which is accompanied by a larger oval II' having point L_2 in common with the inner oval. It is possible to start from m and attain this point; it is also possible to pass beyond it and reach the space outside the large oval. The initial velocity, however, must be at least equal to that required to reach L_2. Hence, *L_2 is a centre of liberation with the same characteristics as L_1.* If we were to reach L_2 with a velocity of zero in relation to the rotating disc, we should stay there eternally, gravitating with m around M as if the body were connected rigidly to these two masses. A calculation of the distance from L_2 to the centre of the Earth—using the same hypotheses as in the calculation of the distance of L_1 and in view of the extreme mass-ratio of 3.3×10^{-5} between the Earth and the Sun, again yields 1,530,000 kilometres, but this time away from the Sun.

So far we have presented no possibility of entering the space between curve II and oval II'. In order to do so we should have to start with an initial velocity smaller than that required to reach L_2. This causes a "hole" to appear at L_2, providing access to the space beyond the large oval. Curves II and II' move nearer together as the initial velocity is increased, finally to merge into a continuous, closed curve. This curve limits yet another inaccessible region. Once outside, however, the only way back to m is through the "hole" at L_2, if we do not wish to consume energy to enter the "forbidden" zone—which, of course, becomes smaller as the initial velocity is increased. Finally, this zone also assumes the shape of the two sausages above and below the straight line, and has a double point at L_3, the *third centre of liberation* on the straight line connecting the Earth and the Sun. If we were to reach L_3 with a velocity equal to zero, we should be able to travel either left or right, but not into the two sausages; *i.e.*, we should again gravitate with m about M. If we wish to travel through these two forbidden zones, then we should have to start with an initial velocity corresponding to a still smaller value for C. The two sausages then separate at L_3 into two closed curves above and below the line Mm. As C_o is decreased they become smaller and smaller, finally shrinking, for a minimum value of C_o, *i.e.*, a maximum initial velocity into two isolated points L_4 and L_5, which each form an equilateral triangle with M and m, having sides 149,000,000 kilometres in length in the case of the Sun-Earth system.

The velocity required to reach either L_4 or L_5, starting from m, is practically equal to the *parabolic velocity* or *escape velocity* at the surface of m, which amounts to 11.2 kilometres per second for the Earth. *Following a departure at this velocity, or at any velocity exceeding it, no zone is inaccessible,* and we could reach any point in the solar system.[2] Points L_4 and L_5 are likewise centres of liberation; and a mass reaching one of them with a velocity equal to zero would stay there eternally, forming an equilateral triangle with M and m.

* * *

The mathematical and physical significance of equation *(6)* has now been explained in brief. The curves which we have discussed—these are also referred to as limit curves or zero-velocity curves—delimit the range for a given initial velocity. They represent the greatest altitudes which can be attained after departing from m with a given initial velocity. We might aptly call them altitude lines (cf. Figs. 3 and 4).

Masses M and m might be conceived as each resting at the bottom of a deep crater. They are dominated by mountains whose height is characterized by the amount of kinetic energy consumed in scaling them. The greatest elevations are at L_4 and L_5. Between the two full-line curves I and I' (Figs. 2 and 4) may be seen the dot-dash curves II and II' denoting a greater altitude. The "terrain" rises from m to L_2 and then falls again along the line Mm. On the other hand, perpendicular to Mm it continues to rise up to points L_4 and L_5. The point L_2 therefore forms a pass. The same applies to points L_1 and L_3.

This can be made clearer by means of suitable shading. Fig. 4 represents the preceding (Fig. 2) in relief, illuminated from the left. The mountains can now be clearly seen. L_1 is a pass over which we can travel from m to M using the smallest amount of energy. Pass L_2 is the most comfortable route towards the exterior, and enables us to avoid summits L_4 and L_5. On the way back we must also cross this pass if we have not enough energy in reserve to surmount the mountain ridge at some other point.

Should we wish to return once we are outside, we shall have to apply fresh energy. This is because the mountain slopes down again towards the exterior. *The main crest runs from L_3 via L_4 to L_2. It is characterized by equal values for gravitational and centrifugal force (rotating disc); but it is only in the centres of liberation that these forces act in opposite directions.* On the inner slopes of the mountains the force of gravity is greater than the centrifugal force; on the outer slopes the centrifugal force is the greater of the two. Consequently, if a mass were left to its own resources with an initial velocity equal to zero on one of the slopes, it would always begin by descending. It would leave the isohypse (elevation line) on which it was deposited, in a direction perpendicular to this line, though only initially. It would cross the very next line in a direction other than perpendicular.

Let us, for example, deposit a mass on the crest between L_3 and L_4. At first it moves along the crest from L_4 towards L_3. If our system of axes likewise turns in the direction from L_4 to L_3, the body will have, after the first unit of time, a linear velocity in excess of that of the point at which it is situated. Its centrifugal force will therefore be greater, driving it towards the outer slope.

Exactly the opposite would happen between L_5 and L_3. In this case, after the initial unit time, the mass would have a velocity smaller than that of the point where it is situated, so that it is pulled down by gravity into the crater. But it would not descend uninterruptedly, since its increasing velocity would cause its direction constantly to change. It might happen—as would generally be the case—that it climbed up again due to the centrifugal force exceeding the gravitational force. Equation *(6)* permits of no method of direct determination of the trajectory described by a mass in any particular case. It would be necessary to follow the mass step by step.

One fact, however, is certain: the mass will never be able to surmount the isohypse from which it started with a velocity equal

[1] Cf. last-but-one paragraph of this article.

[2] The duration of such a trip is not taken into consideration here.

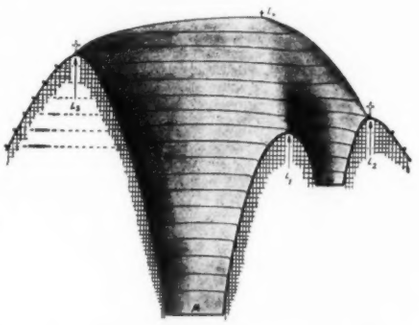


Fig. 3: View of the "gravity terrain" pertaining to Fig. 2 in elevation. The altitudes are proportional to the amount of kinetic energy consumed in ascending them.

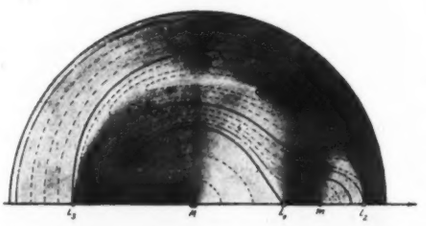


Fig. 4: Plan of the "gravity terrain" pertaining to Fig. 2, with lines of elevation. The illumination is from the left.

to zero. In this regard, the terrain behaves like a surface on which a sphere rolls without friction.

On the crest of the mountains the resultant of the gravitational and centrifugal forces follows the line of the crest itself. This is shown in Fig. 5, where the crest is denoted by a dot-dash line. The forces acting at any point along the crest are represented to scale. All along the crest the centrifugal force F and force of gravity K are equal (in relation to the rotating system), but act in opposite directions only at the centres of liberation. Their resultant R lies at a tangent to the direction of the crest and is always perpendicular to the isohypse at this point. The resultant is, of course, zero at the centres of liberation.

* * *

We now have a detailed chart of the terrain through which we wish to travel some day. For the present, however, we are crawling along the very bottom of the crater m. The depth of the crater depends not only on the masses as such, but also on the geometric dimensions of the masses. The depth is therefore principally determined by the density of M and m, which also determine the force of gravity at the surface of these masses. The scale in Fig. 3 does not permit them to be drawn right to the bottom, as their depth is a multiple of the difference in altitude between L_1 and L_4. In practice, the problem of interplanetary travel will be solved once we are able to reach the first centre of liberation, L_1.

In the Earth-Sun system, point L_1 is situated at some 240 times the earth's radius from the centre of the Earth (about 1,530,000 kilometres), whereas the neutral point N, where the forces of gravity of the Earth and the Sun are equal, is only 40 radii away (cf. Fig. 5). The Moon gravitates around the Earth at a distance of 60 terrestrial radii, so that it is always further away from the Earth than the neutral point. This means that the attraction exerted on it by the Sun is greater than that of the Earth. The Moon's trajectory is therefore principally determined by the Sun and is always concave towards the Sun. The Earth only disturbs the movement of the Moon. At full moon the curve of its trajectory is more accentuated that at new moon. Hence the Moon is not really a pure satellite of the Earth! It moves around the Sun with the Earth because it always stays inside the crater m and, as we have already seen, it cannot leave this crater without some outside influence. The Earth and the Moon therefore form a double planet.

Similarly, a rocket which, because of an insufficient initial velocity, cannot pierce the small oval I around m, will continue to accompany the Earth. It would be a pure satellite if it could not escape from the oval containing the neutral point—*i.e.*, if it could not ascend more than 40 terrestrial radii following a vertical launching. The only way to create an artificial planet is to travel over pass L_1. This planet would join company with the inner planets Venus and Mercury, for it would gravitate in the crater M. In order to create an artificial planet gravitating around the Sun outside the Earth's orbit, the pass at L_2 would have to be crossed.

In this study we have simplified matters by ignoring the presence of the Moon. But

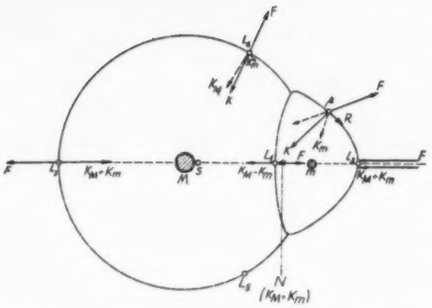


Fig. 5 : The five centres of liberation of the rotating Sun-Earth system :

In each of points L_1 to L_5 the centrifugal force and the resultant force of gravity are equal and act in exactly opposite directions. A mass deposited at one of these points at an angular velocity equal to that of m about the centre of gravity of the system $M + m$, *i.e.*, having a relative velocity $v = o$, would have no inclination to leave that point. At the neutral point N, the forces of gravity of M and m are equal, but a mass deposited there would immediately be driven towards the outside by centrifugal force, which is not allowed for here.

$$\text{Gravity relative to } M = K_M = f\frac{M}{R^2_M}$$

$$\text{Gravity relative to } m = K_m = f\frac{m}{R^2_m}$$

$$\text{Centrifugal force acting on } \mu = F = \mu R_M \omega^2$$

it is possible to construct an identical " gravity terrain " for any system of two masses —*e.g.*, for the Earth and the Moon. The system of axes would then rotate at the same angular velocity as the Moon about the Earth. The first centre of liberation would be at a distance of 50 terrestrial radii from the centre of the Earth (between the Earth and the Moon), and the neutral point at 54 such radii. For the time being we may ignore the presence of other planets, since they are all very distant. However, the Moon produces " bumps " in our " gravity terrain," which, being far from negligible, complicate considerably the problem of navigation through space. Hitherto we have regarded the problem of the spaceship as a problem of three masses ; but sending a rocket to the Moon involves a problem of four masses when one takes into account the Earth, the Moon and the Sun. On the other hand, a true Earth satellite, such as we have defined above, involves a problem of only three masses and even—in first approximation—of only two masses, though possibly with some disturbances.

We have said our piece. It is now for the engineers to speak. They must provide us with the technical means of surmounting passes L_1 and L_2, first of all in the Earth-Moon system, and later in the Earth-Sun system. That will enable us to overcome the domination of the Earth. After that, it will be for the astronomers to take the helm and navigate their spaceships safely and soundly across the interplanetary ocean.

Aircraft Engines of the World 1950. — By Paul H. Wilkinson, published by Paul H. Wilkinson, New York.

Even the new yearbook still lists about a hundred piston engines, including a number of compound engines. Of particular interest this time however is the progress achieved in turbo power units : Newcomers to the list are the Allison T-38 and T-40 for propellor drive, and the General Electric J-47, Pratt & Whitney J-48, De Havilland " Goblin-4 "; Rolls-Royce " Avon ", Avro Canada " Orenda " and Armstrong Siddeley " Adder " jet power units.

The tables and technical data are supplemented by a detailed commentary on the present stage of development of aircraft power units. This also indicates the direction in which future progress can be expected. Comprehensiveness and accuracy also characterise the new edition of Wilkinson's Yearbook.

Zur Statik von dünnen Flugzeug-Tragflächen. — By Dr. Ing. H. Schürch — Paper No. 2 of the Institut für Flugzeugstatistik und Flugzeugbau, Eidg. Technische Hochschule, Zurich — Published by Leeman, Zurich 1950.

This paper deals with the structural analysis of wings for aircraft construction. As is known, design elements are used here to which the normal methods of structural analysis cannot be directly applied. This is particularly so in the case of wings and tail units of modern design, in which the load-carrying material is spread more or less evenly over the surface. Stress and deformation conditions are thus no longer one-dimensional, but at least two-dimensional.

The writer considers the possibility of simplifying the static analysis of wings to such an extent that traditional methods of structural analysis suffice. By an extension of the theory of flexible plates, he succeeds in creating mathematical formulae for the relationship between load and deformation of a " sandwich " type wing. The " sandwich " is a plate of variable height with rectangular stiffening, which differs from the usual wing design in that it has a shearing system (ribs and stringers) which is continuously distributed. On solution of the deformation equation of the sandwich wing the stress is broken down into three components : a bending moment in the direction of the spar, a torsional moment, and a bending moment in the direction of the ribs. In the practical part of the paper a number of examples are examined mathematically in proof of the practical utility of the theoretical methods of calculation. The investigations were also extended to extremely swept-back and Delta wings. (German, with English summary.)

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